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PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of

Rothermel et al.

Appln. No.: 10/813,495 Group Art Unit: 2651

Confirmation No.: Examiner:

Filed: March 30, 2004

For: WRITE HEAD ALIGNMENT FOR FULL AMPLITUDE TIME BASED SERVO

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THIRD PARTY SUBMISSION OF ART (37 C.F.R. § 1.99)

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

Pursuant to 37 C.F.R. § 1.99, the undersigned respectfully submits the following documents, attached hereto:

U.S. Publn. No. 2005/0168869 (August 4, 2005)

U.S.P. 4,996,609 (February 26, 1991)

The fee pursuant to 37 C.F.R. § 1.17(p) is to be charged to Deposit Account No. 19-4880.

The undersigned further certifies that a copy of this paper identifying the above documents was served by First Class Mail to the attorney of record, Mr. Eric Levinson of Imation Corporation, at the address of record P.O. Box 64898, St. Paul, MN 55164-0898, as required by 37 C.F.R. § 1.284.

This submission is being submitted prior to allowance, but after two months from the publication of 2005/0219734, the fee under 37 C.F.R. § 1.17(i) is to be charged to Deposit Account No. 19-4880.

12/12/2005 HDESTA1 00000010 194880 10813495

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01 FC:1806 180.00 DA

SUBMISSION UNDER 37 C.F.R. § 1.99
U.S. Appln. No. 10/813,495

The undersigned submits that the above-identified application was redocketed to the Examiner on November 1, 2005 and accordingly, it is anticipated that examination will result in amendments to the claims which will alter the scope of the claims that cannot be anticipated during the relevant time period, analogous to conditions indications referenced by MPEP 1134.01(I).

Accordingly, this submission complies with 37 C.F.R. § 1.99.

Respectfully submitted,

Susan Perng Pan
Registration No. 41,239

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WASHINGTON OFFICE
23373
CUSTOMER NUMBER

Date: December 9, 2005

Tech - Support Staff Structure

Technology Center 2600

Effective: 1-9-06

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Art Unit	HSLIE:	Ext.	Loc.
	Earline Green	2-2993	2A25
	SLIE:		
	John Epps	2-3006	3A54
	LIE:		
2631	Debra Savoy	2-2995	2A80A
2632	Terri Williams	2-2991	2D80A
2633	Sharon West	2-2996	2A08B
2634	Lashawn Marks	2-2997	2A80B
2635	Terri Williams	2-2991	2D80A
2636	Marquetta McGee	2-2956	2D08C
2637	Debra Savoy	2-2995	2A80A
2638	Lashawn Marks	2-2997	2A80B
2661	Anthony Williams	2-2999	2A08A
2662	Joy Dobbs	2-3001	2D08A
2663	Joy Dobbs	2-3001	2D08A
2664	Jacqueline Weir	2-3002	3D80A
2665	Marcia Gordon	2-3003	2D80C
2666	Tara Witcher	2-2990	2D80B
2667	Phyllis Deloatch	2-2987	3D80B
2668	Tara Witcher	2-2990	2D80B
	LDRC:		
	Lamont McLauchlin	2-3004	2A80C
	Robert Sherman	2-3005	2A08C

Team 2 (Knox Bldg.)			
Art Unit	HSLIE:	Ext.	Loc.
	Arthur McCloud	2-7268	8D51
	SLIE:		
	Patience Resper	2-7276	8B49
	LIE:		
2611	Wanda Lawson	2-7266	6A08A
2612	Barbara Alexander	2-7018	07D78
2613	Patsy Zimmerman	2-7289	6D08B
2614	Josephine Douglas	2-7249	6A80B
2615	Jacqueline Couplin	2-7245	6D08A
2616	Minnie Jackson	2-7261	6A08B
2617	Patsy Zimmerman	2-7289	6D08B
2671	Monica Harris	2-7256	7A10A
2672	Vincent Butler	2-7237	7D18A
2673	Kim Pannell	2-7271	7D10A
2674	Nichele Peterson	2-7273	8D10A
2675	Laticia Tyson	2-7285	8D18B
2676	Katrina Harling	2-7254	8D18A
2677	Nichele Peterson	2-7273	8D10A
	LDRC:		
	Pamela Rogers	2-7279	6D08C
	Evangeline Harris	2-7255	7D18C

Team 3 (Knox Bldg.)			
Art Unit	HSLIE:	Ext.	Loc.
	Earline Green	2-2993	2A25
	SLIE:		
	Stacey Kemper	2-7265	7A54
	LIE:		
2621	Davina Butler	2-7236	8A70B
2622	Kenneth Davis	2-7247	8A70A
2623	Bonnie Phoenix	2-7274	8A18B
2624	Tammy Acree	2-7017	8A78A
2625	Sharone Moore	2-7269	8A10A
2626	Chantae Dessau	2-0518	8A18A
2627	Kenneth Davis	2-7247	8A70A
2681	Jason Eaddy	2-7251	7A18B
2682	Trina Riddick	2-7277	7A18A
2683	LaWanda Dillon	2-7248	7A70A
2684	Anthony Tyson	2-7284	7A70B
2685	Audrey (Denise) Hopkins	2-7259	5D08B
2686	Linda Badie	2-7019	7A78A
2687	Linda Badie	2-7019	7A78A
2688	Jason Eaddy	2-7251	7A18B
	LDRC:		
	Theresa Lindsay	2-7267	8A18C
	Stephen Hoover	2-7258	8A70C

Team 4 (Knox Bldg.)			
Art Unit	HSLIE:	Ext.	Loc.
	Arthur McCloud	2-7268	8D51
	SLIE:		
	Kimberly Spears	2-7282	6B49
	LIE:		
2642	Shirell Carmichael	2-7238	7D70B
2643	Tracie Robertson	2-7278	6D80B
2644	Shirell Carmichael	2-7238	7D70B
2645	Vernon Towler	2-7283	6A80A
2646	Tracie Robertson	2-7278	6D80B
2651	Marquita Jones	2-7263	7D70A
2652	Stanley Jordan	2-7264	7D18B
2653	Marquita Jones	2-7263	7D70A
2654	Andrea Burden	2-7235	6D80A
2655	Karen Vestal	2-7286	7D70C
2656	Karen Vestal	2-7286	7D70C
	LDRC:		
	Diane Johnson	2-7262	6D80C
	Wanda Nelson	2-7270	7A18C

United States Patent [19]

Joannou

[11] **Patent Number: 4,996,609**

[45] **Date of Patent: Feb. 26, 1991**

[54] **MAGNETIC HEAD RECORDING MULTITRACK SERVO PATTERNS**

[75] Inventor: **Kyriacos Joannou**, Wayland, Mass.

[73] Assignee: **Pericomp Corporation**, Natick, Mass.

[21] Appl. No.: **313,719**

[22] Filed: **Feb. 22, 1989**

[51] **Int. Cl.**^{5} **G11B 5/02**

[52] **U.S. Cl.** **360/57**; 360/77.010; 360/121

[58] **Field of Search** 360/55, 57, 77.06, 77.11, 360/119, 121, 77.01

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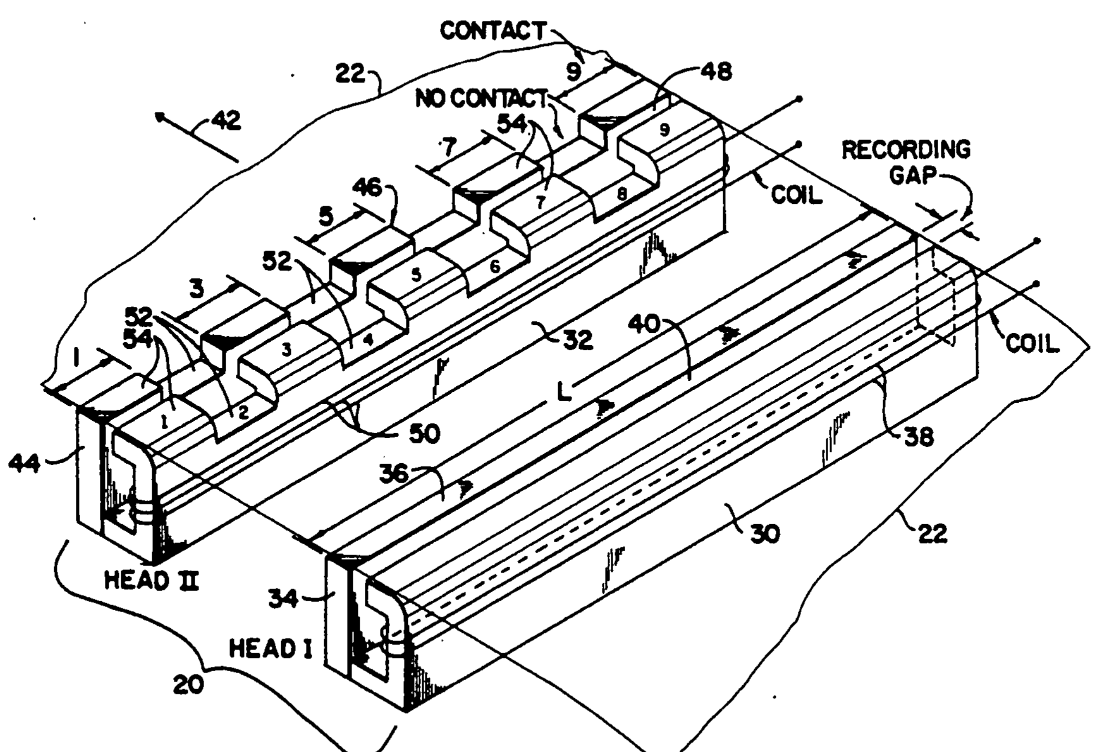
Primary Examiner—Aritotelis M. Psitos
Assistant Examiner—David L. Robertson
Attorney, Agent, or Firm—Schiller, Pandiscio & Kusmer

[57] **ABSTRACT**

A novel apparatus and method is described for recording a pattern of track positioning servo signals at select locations of a magnetic tape for use in aligning a single track read head with each of the tracks defined by the signal pattern. The pattern is provided by recording two different signals with two write heads so that the signals are recorded as alternating strips. The differences between the two signals are then used to define the each track center.

34 Claims, 7 Drawing Sheets



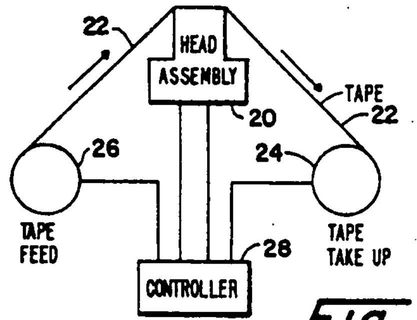

HEAD
ASSEMBLY
22
TAPE
22
20
26
24
TAPE
FEED
TAPE
TAKE UP
28
CONTROLLER

Fig. 1

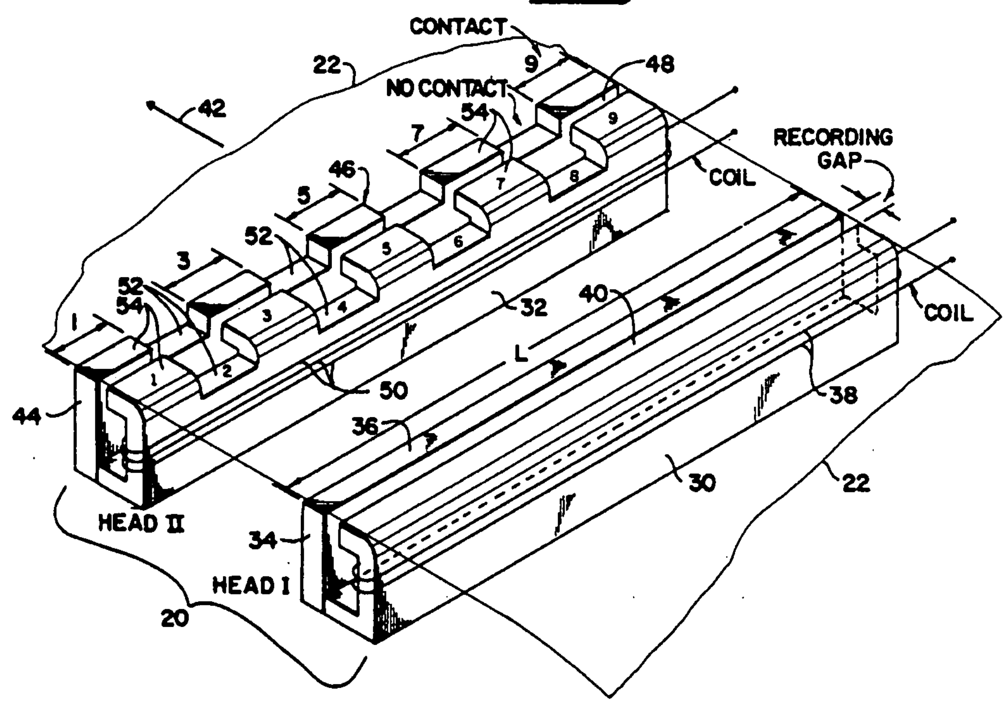

CONTACT
22
9
48
NO CONTACT
42
54
7
RECORDING
GAP
46
COIL
5
52
3
32
40
COIL
52
54
50
L
38
44
36
30
22
HEAD II
34
HEAD I
20

Fig. 2

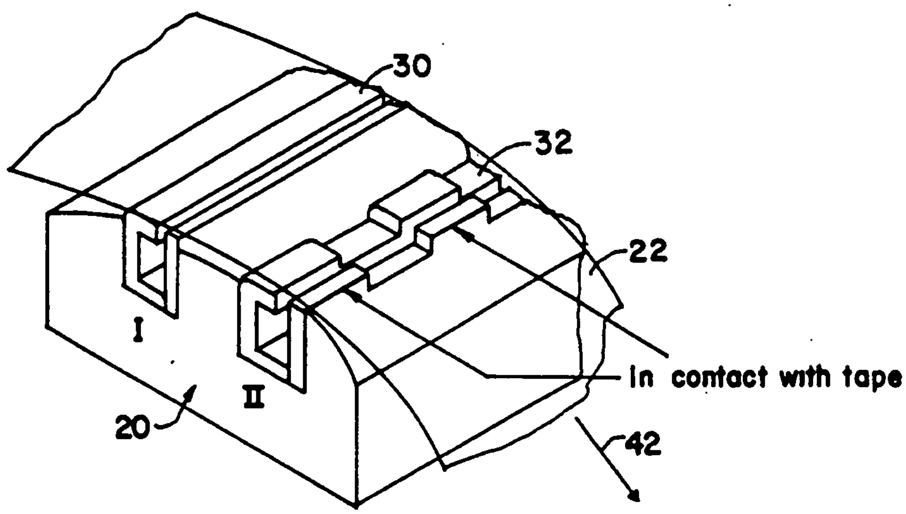

30
32
22
I
II
In contact with tape
20
42

Fig. 3

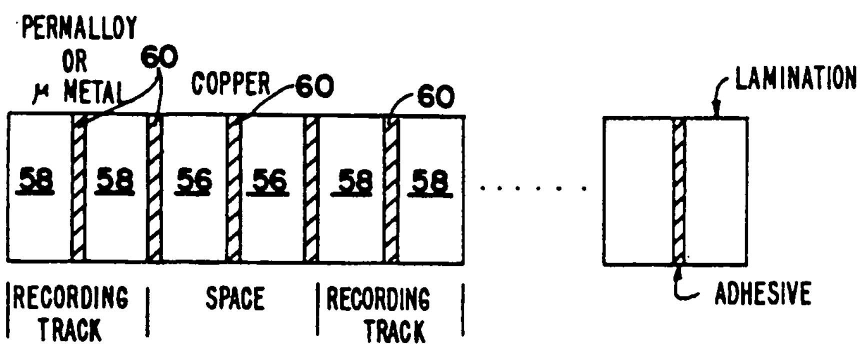

PERMALLOY
OR
μ METAL
60
COPPER
60
60
LAMINATION
58
58
56
56
58
58
ADHESIVE
RECORDING TRACK
SPACE
RECORDING TRACK

Fig. 4

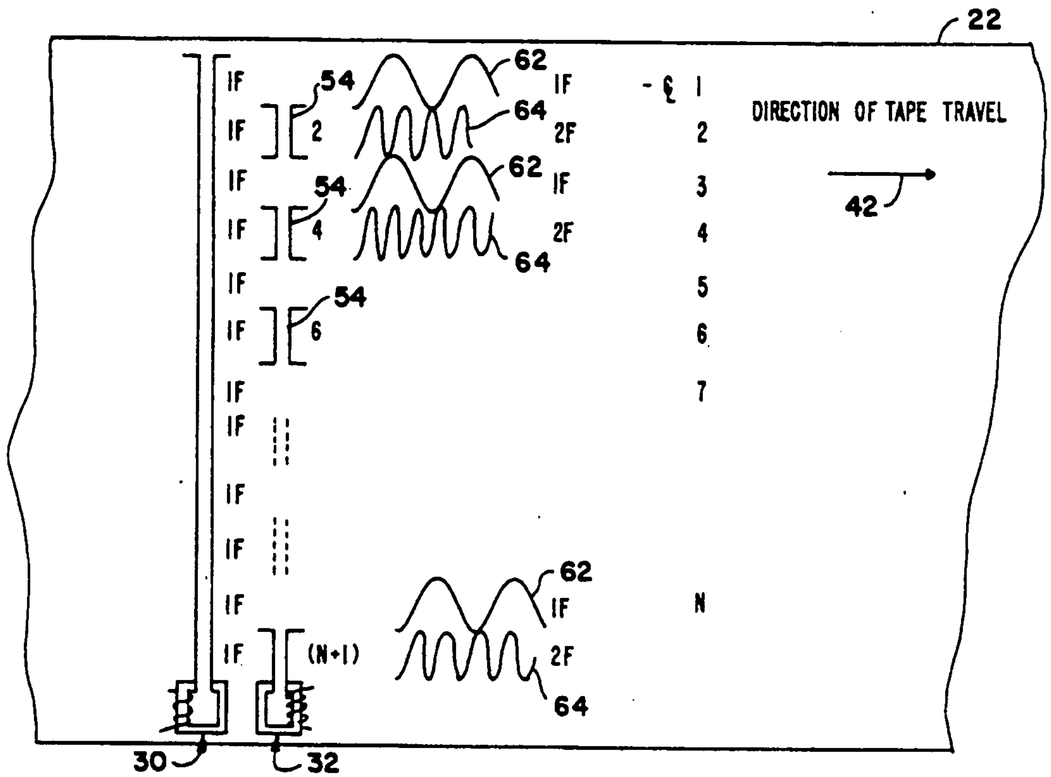

22
IF
54
62
IF
1
DIRECTION OF TAPE TRAVEL
IF
2
64
2F
2
IF
54
62
IF
3
42
IF
4
2F
4
64
IF
5
54
IF
6
6
IF
7
IF
IF
IF
62
IF
N
IF
(N+1)
2F
64
30
32

Fig. 5

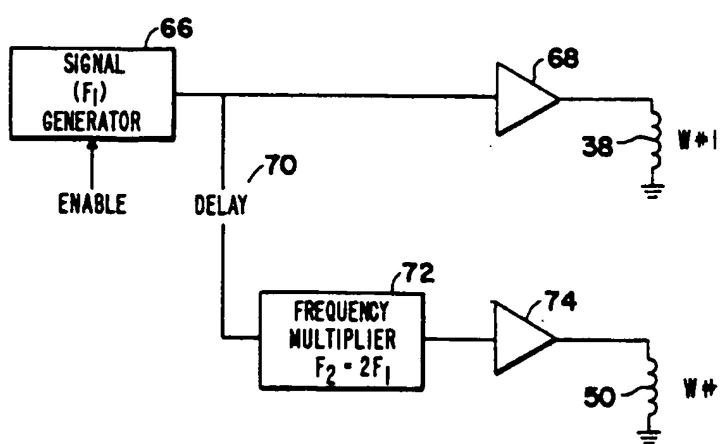

66
SIGNAL
(F_1)
GENERATOR
ENABLE
DELAY
70
68
38
W#1
72
FREQUENCY
MULTIPLIER
$F_2 = 2F_1$
74
50
W#2

Fig. 6

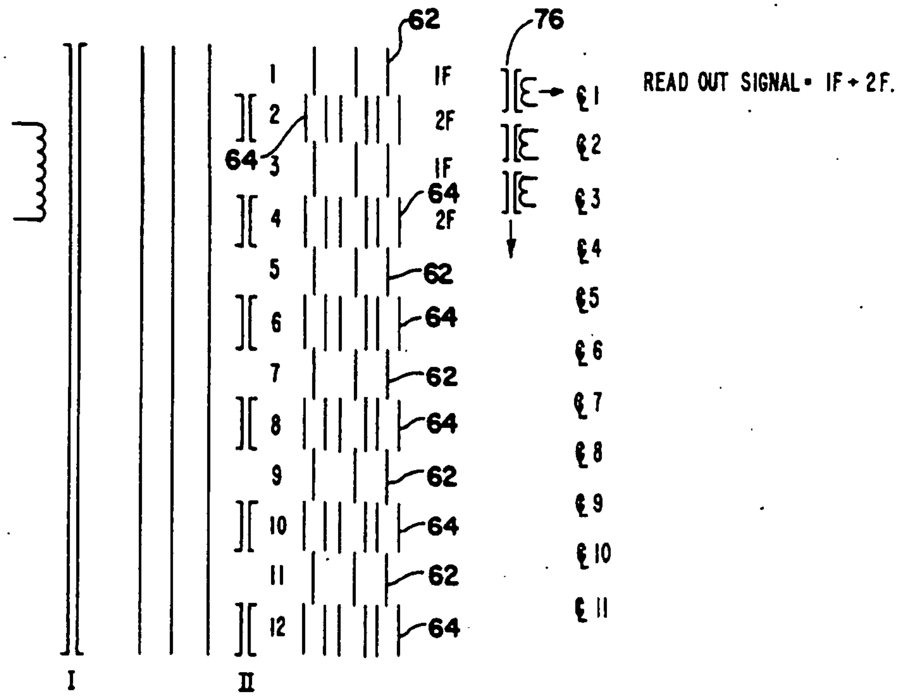

62
76
1
IF
READ OUT SIGNAL = IF + 2F.
2
2F
64
3
IF
4
64
2F
5
62
6
64
7
62
8
64
9
62
10
64
11
62
12
64
I
II

Fig. 7

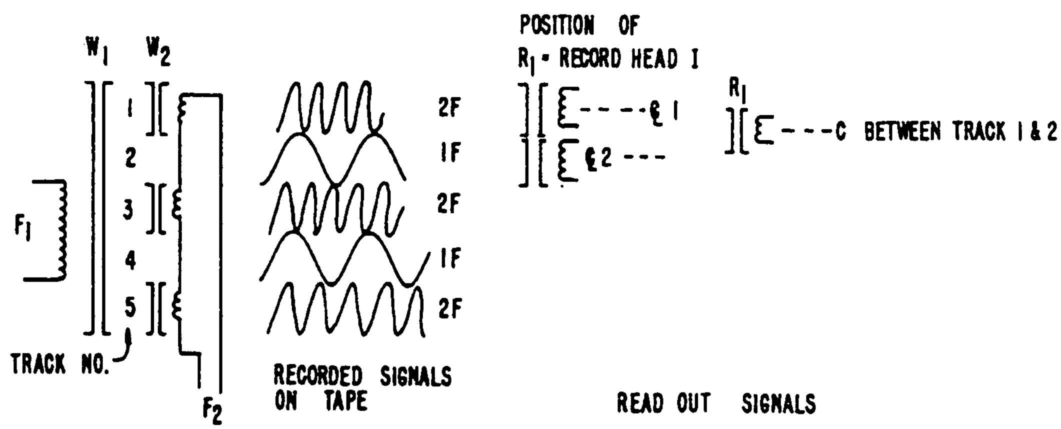

W1
W2
POSITION OF
R1 = RECORD HEAD I
R1
1
2F
2
IF
C BETWEEN TRACK 1 & 2
F1
3
2F
4
IF
5
2F
TRACK NO.
RECORDED SIGNALS ON TAPE
READ OUT SIGNALS
F2

Fig. 8

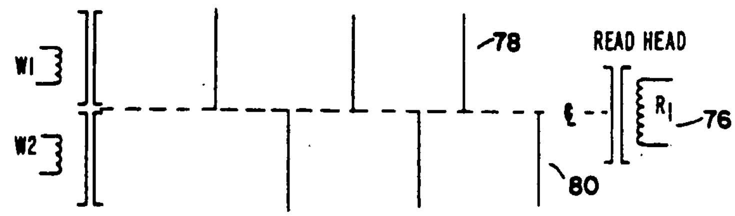


Fig. 9

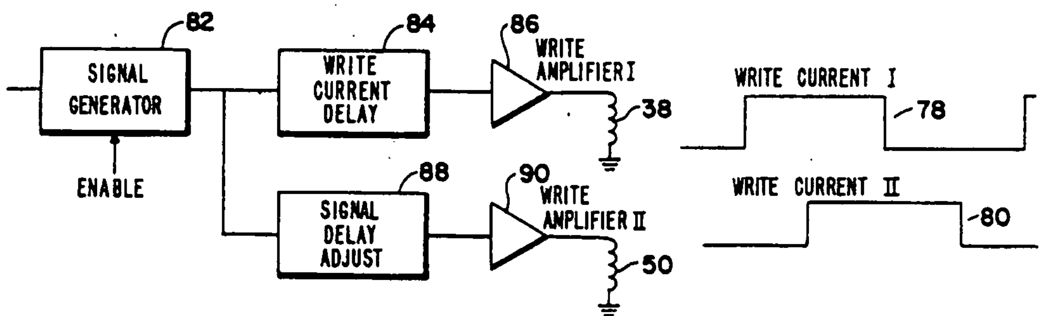


Fig. 10

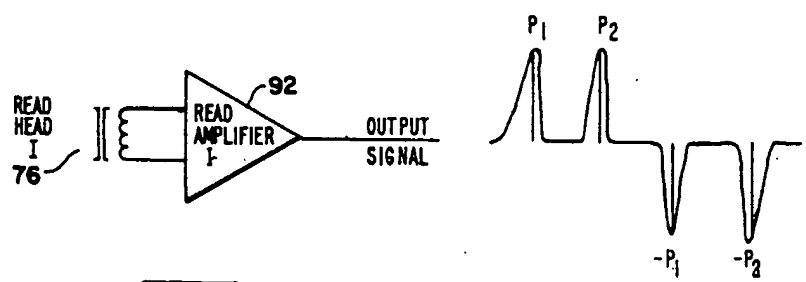


Fig. 11

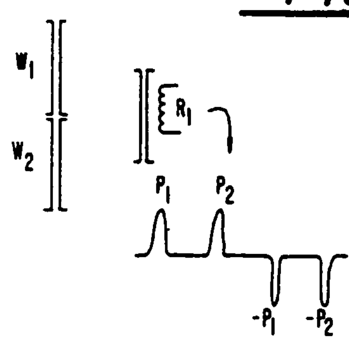


Fig. 12a

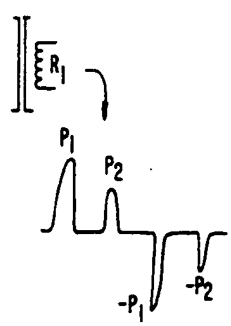


Fig. 12b

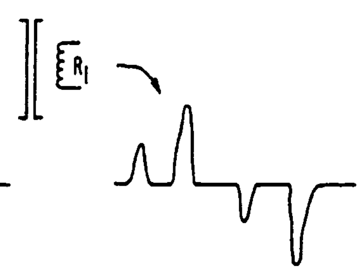


Fig. 12c

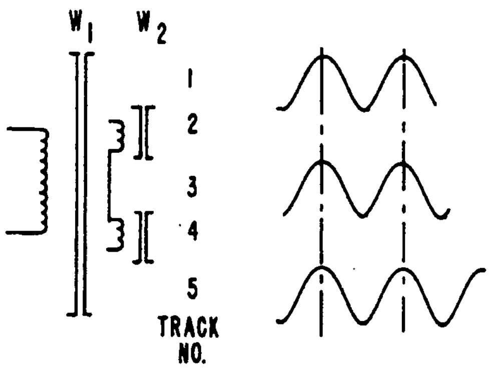


Fig. 13a

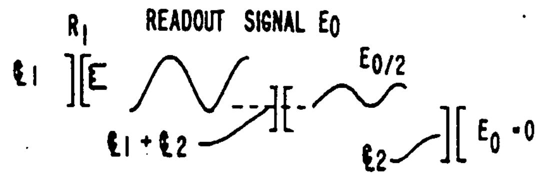


Fig. 13b

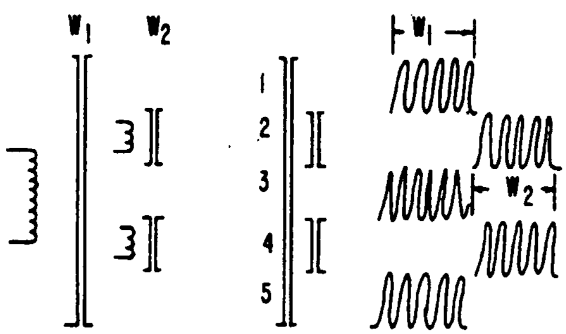


Fig. 14a

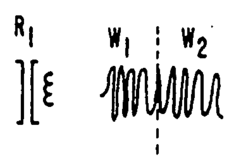


Fig. 14b

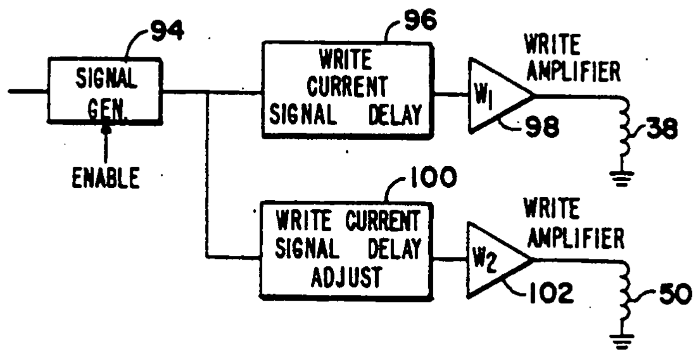


Fig. 15a

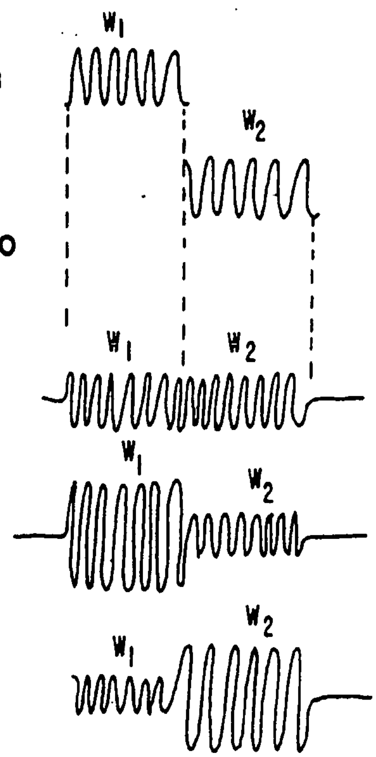


Fig. 15b

MAGNETIC HEAD RECORDING MULTITRACK SERVO PATTERNS

The present invention relates to accurate servo control alignment of a movable magnetic read head relative to each of the tracks of a multi-track magnetic data storage medium, and more specifically to a method of and apparatus for quickly and reliably prerecording servo control signals on a magnetic data storage medium for use in accurately controlling the position of a movable single track magnetic read head relative to each track.

For years the magnetic recording industry has been looking for ways to increase the data storage density of magnetic data storage media such as tape, and yet avoid problems such as mistracking. The amount of data stored on a particular sized tape, for example, is a function of both data packing density, how much data can be packed on each track, and the spacing between tracks. Obviously, the closer the tracks, the more data that can be stored on a specific length of tape. For example, commercially available magnetic tape for serving as a back up to other storage systems such as hard magnetic disks, or simply used for storing archival information, is capable of storing enormous amounts of information. Track widths currently range between 0.003 and 0.013 inches with narrower track widths less than 0.003 inches being tested in the industry. One of the limitations on increasing storage density beyond what is currently possible, particularly on cartridge tapes for storing digital information, is that the read/-write magnetic heads used in the tape drives for storing and retrieving data from the tapes tend to be inexpensively made. The heads usually are made to read one track at a time so that a head positioning servo system must be provided for moving the head from track to track resulting in certain tolerances relating to such movement that limit track density.

More specifically, there are presently two common approaches for servo controlling a single track head relative to each track of a multi-track tape. One approach currently used by a majority of quarter inch tape drive manufacturers includes the step of recording a burst signal of information on one track at the beginning of the tape. This is the reference or zero track. The zero track is usually identified and defined by a line a predetermined distance from and parallel to an edge of the tape so that the head position servo control moves the single track read head relative to the edge to the zero track by the head's relative distance from the edge. The head positioning servo control seeks automatically to verify its center line with the center line of the zero track by stepping the read head toward or away from the reference edge (that is "up" or "down") in microsteps to find the burst signal at its maximum level. All other track center lines are then defined by corresponding predetermined distances from the reference track. The distance between the zero track and each of the other tracks is therefore measured with a tolerance depending on the resolution of the stepping mechanism for moving the magnetic head. Thus, the number of tracks on the recording medium is dependent upon the tolerances of the stepping mechanism, with 9 to 18 tracks being typical for quarter inch tape. The head positioning servo control moves the head the measured distance without any verification of accuracy.

Thus, a major problem with this first approach is that the track location is dependent upon the hardware since the hardware must accurately locate the zero track relative to the reference edge and then, when appropriate, locate a particular track with respect to the zero track. As a result a user may find it difficult to retrieve data from a tape using a tape drive which is different from the tape drive used to record the data due to incompatibilities of the two tape drives.

The other type of common head positioning system utilizes a prerecorded pattern of tracking or servo signals on each track to position the head accurately on each track. To record the servo pattern on each track is a time consuming process requiring as many passes of the tape from beginning to end as there are tracks. This process is very costly with the cost of the prerecorded tape depending on the number of tracks and the tape length. The time required to record servo patterns on the tape is directly proportional to the number of tracks for a specific length of tape. Typical lengths of tape in commercially available cartridges are 200 to 600 feet with 12 to 32 tracks usually being defined. It is obvious that this method of head positioning yields higher accuracy of tracking. It is also obvious that it is extremely time consuming to record the servo pattern on each track and much more costly to the tape cartridge manufacturers as when the first approach is used. For example, assuming a tape having a length of 200 feet is provided with 12 recording tracks, the time required to record a servo pattern using this second approach at a velocity of 50 inches per second each of the tracks would be in the range of 10 minutes plus a formatting time of an additional 10 minutes approximately. For 600 foot tapes and 24 recording tracks it would take approximately 2 hours to perform the recording of servo patterns and formatting. It can be seen therefore that the cost of such a servo pattern is prohibitive.

Accordingly, it is a general object of the present invention to reduce or substantially overcome the above-mentioned problems of the prior art.

More specifically, an object of the present invention is to provide an improved technique of precisely recording a pattern of servo signals for each track of a multi-track recording medium in a minimum amount of time.

And another object of the present invention is to provide an improved technique of recording a pattern of servo signals for each track of a multi-track magnetic recording tape in a predetermined period of time as a function of tape speed and tape length and irrespective of the number of channels.

And yet another object of the present invention is to provide an improved apparatus for carrying out the technique of the present invention.

These and other objects of the present invention are achieved by apparatus for prerecording track positioning signals on a magnetic recording medium so as to accurately and simultaneously predefine a plurality of spaced apart recording tracks on the recording medium across the recording width of the medium. The apparatus comprises:

magnetic head means for simultaneously writing a track positioning signal pattern across the recording width of the magnetic recording medium so as to simultaneously define the positions of the tracks on the medium as a function of the locations of the signals on the medium, the magnetic head means comprising (a) a first write head for recording a

first signal pattern on the recording medium, and (b) a second write head, spaced from the first write head, for recording a second signal pattern on the recording medium so that the first and second signal patterns combine to create the track positioning signal pattern;

means for moving the magnetic recording medium relative to the first and second write heads so that the track positioning signal pattern is recorded on the medium; and

means, coupled to the first and second write heads, for generating the first and second signal patterns as the recording medium is moved relative to the magnetic head means.

In accordance with another aspect of the present invention an improved method is provided for prerecording track positioning signals on a magnetic recording medium so as to accurately and simultaneously predefine a plurality of spaced apart recording tracks on the recording medium across the recording width of the medium. The method comprises the steps of:

simultaneously writing a track positioning signal pattern across the recording width of the magnetic recording medium so as to simultaneously define the positions of the tracks on the medium as a function of the locations of the signals on the medium, the step of writing comprising (a) recording a first signal pattern on the recording medium, and (b) recording a second signal pattern on the recording medium so that the first and second signal patterns combine to create the track positioning signal pattern;

moving the magnetic recording medium so that the track positioning signal pattern is recorded on the medium; and

generating the first and second signal patterns as the recording medium is moved.

Other objects of the invention will in part be obvious and will in part appear hereinafter. The invention accordingly comprises the several steps and the relation of one or more of such steps with respect to each of the others and the apparatus possessing the construction, combination of elements, and arrangement of parts all of which are exemplified in the following detailed disclosure and the scope of the application of which will be indicated in the claims.

For a fuller understanding of the nature and objects of the present invention, reference should be had to the following detailed description taken in connection with the accompanying drawings wherein:

FIG. 1 is a partial block and partial schematic diagram of the apparatus of the present invention;

FIG. 2 shows a perspective view of the preferred embodiment of the write head assembly of the apparatus illustrated in FIG. 1;

FIG. 3 shows a perspective view of the preferred embodiment of the write head assembly of the apparatus shown in FIG. 1 and modified so as to be mounted in a single housing;

FIG. 4 shows a cross-section of a portion of a magnetic write head made in accordance with the teachings of the present invention;

FIG. 5 shows a track positioning signal pattern recorded on a tape in accordance with the method of the present invention;

FIG. 6 shows a partial block and partial schematic diagram of signal generating means for generating the track positioning signal pattern shown in FIG. 5;

FIG. 7 illustrates a technique of defining the center lines of the multiple tracks defined by the pattern shown in FIG. 5 so that the read position of the single read head can be appropriately positioned with respect to each track;

FIG. 8 shows an alternative of defining the center lines of the multiple tracks defined by the pattern shown in FIG. 5;

FIG. 9 shows an alternative track positioning signal pattern recorded on a tape in accordance with the method of the present invention;

FIG. 10 shows a partial block and partial schematic diagram of signal generating means for generating the track positioning signal pattern shown in FIG. 9;

FIGS. 11, 12*a*, 12*b* and 12*c* illustrate a technique of defining the center lines of the multiple tracks defined by the pattern shown in FIG. 9 so that the read position of the signal read head can be appropriately positioned with respect to each track;

FIGS. 13*a* and 13*b* show an alternative track positioning signal pattern recorded on a tape in accordance with the method of the present invention and also illustrates a technique of reading the track positioning signal pattern shown in that Fig.;

FIGS. 14*a* and 14*b* show yet another alternative track positioning signal pattern recorded on a tape in accordance with the method of the present invention and also illustrates a technique of reading the track positioning signal pattern shown in that Fig.; and

FIGS. 15*a* and 15*b* show a partial block and partial schematic diagram of signal generating means for generating the track positioning signal pattern shown in FIG. 14 and variations of that pattern.

In the drawings the same numerals are utilized to refer to the same or similar parts.

In accordance with the present invention the apparatus used to carry out the method is generally shown in FIG. 1, wherein a write head assembly 20 is used to record the track positioning signal pattern on the tape 22. The tape is moved over the assembly 20 by appropriate means in the form of a tape drive 24 for taking up the tape after it moves over the assembly 20, and a tape feed 26 for feeding tape in a a manner well known in the art. A controller 28 controls the tape drive 24, tape feed 26 in a well known manner and provides the necessary signals to the write head assembly 20 to provide the track positioning signal pattern on the tape. As will be more evident hereinafter the controller includes a signal generator for generating two signals which are applied to the tape through two different write or recording heads so as to provide the pattern.

More specifically, the write head assembly 20 includes two write or recording heads such as shown at 30 and 32 in FIG. 2. While the two heads 30 and 32 are shown as two separately mounted components relative to one another, the two heads are preferably mounted on a single housing so as to achieve more accurate registration with the tape 22 as shown in FIG. 3. The first recording head 30 is provided with a core 34 defining a top portion 36 for contacting the tape 22 as the latter is moved over the head and a coil 38 wrapped around the core 34 in a well known manner. A gap 40 is formed in the top portion for creating the magnetic field to which the tape is exposed as the tape moves over the top portion 36. The magnetic field is provided in response to and as a function of the signal applied to the coil 38. The top portion and gap each have a length dimension L substantially equal to the recording width of the record-

ing tape moved over the head (i.e., the dimension of the tape normal to the direction 42 of movement of the tape 22). As will be more evident hereinafter, the signal applied to the tape by the head 30 as the tape is moved over the head will be recorded on substantially the entire width of the tape so as to provide a first recorded signal pattern on the tape. The tape is moved over the head 30 first before it is moved over the head 32.

The head 32 is identical to the head 30 (in that it includes a core 44 having a top portion 46 formed with the gap 48, and a coil 50 for providing a magnetic field across the gap 48 in response to and as a function of an electrical signal applied to the coil 50), except that the top portion is notched so as to provide a plurality of grooves or slots 52 disposed between and therefore defining the recording elements 54. As such as the tape 22 is moved over the head 32, after having been moved over the head 30, the recorded portions of the tape provided with the signal pattern from the head 30 and moved over the slots 52 will remain unaffected since the slots will not contact the tape. The recorded portions of the tape provided with the signal pattern from the head 30 and moved over the recording elements 54, however, will contact the head and therefore will be erased and replaced with the signal pattern provided by the head 32 in response to a signal provided on the coil 50. As will be more evident hereinafter, the composite signal pattern resulting from the first signal pattern recorded by the head 30 and the second signal pattern recorded by the head 32 are used to simultaneously define the specific track positions on the tape in an extremely accurate manner.

The accuracy of the track positions thus defined are in part dependent on the accuracy of the construction of the head 32 and specifically the positions and dimensions of the slots 52 and recording elements 54. Both the contact and noncontact regions defined by the slots 52 and elements 54 must therefore be very precisely formed with relatively low tolerances, e.g., not greater than 3% of the desired track width. The actual head 32 can be constructed in accordance with any one of several methods. For example, recording heads are often made from laminations of magnetic materials bonded together. Keeping in mind that laminations of magnetic materials used in manufacturing magnetic recording heads are rolled with very high precision, slots and recording elements of 0.002 inch wide each can be made with tolerances of 3% of 0.002 inches. As shown in FIG. 4, for example, the non-contact slots 52 can be achieved by using copper laminations, indicated at 56 of the same thickness as the laminations of magnetic core material indicated at 58, typically made of a magnetically conductive material such as a permalloy or ferrite material, all of which are secured together with layers 60 of suitable adhesive.

Another method used to construct the head 32 is to build a core similar to the core of write head 30 which records the full width of the tape and remove material where the non-contact slots 52 are desired. The material can be removed by electrical discharge, for example, with a EDM or electrical discharge machine. The depth of the recessed slots 52 is sufficient so that the the tape portions traveling directly over the slots will be unaffected, with a depth of about 0.006 to 0.010 inches being adequate for the average life of a magnetic head.

A third method by which material can be removed from the surface of the recording heads made out of metal or ferrite material is by laser etching or grinding. The widths of the slots 52 and elements 54 are sufficient so that the tracks defined by the composite track positioning signal pattern provided on the tape 22 will be sufficiently close to one another to provide high track density. The spaces between the tracks can be as wide as the tracks themselves, or narrower if desired, depending on the composite signal pattern recorded on the tape and the method of detection.

For example, as shown in FIG. 5 an example of a composite signal pattern is formed by providing a first sinusoidal signal of a first frequency F_1 to the coil 38 of the first head 30 so that substantially the entire width of the portion of the tape recorded with the first signal is provided with this first signal pattern. This first pattern is indicated by the numeral 62. As this portion of the tape is moved over the head 32 the second signal pattern is formed by providing a second sinusoidal signal of a second frequency F_2 different from F_1, e.g., $F_2=2F_1$. This signal pattern will be recorded over the first signal pattern where the portion of the tape contacts each of the recording elements so as to form strips of a different signal pattern as indicated at numeral 64 from the pattern 62.

The signals at frequencies F_1 and F_2 can easily be generated as shown in FIG. 6, wherein a single signal generator 66 is turned on and off with an enable signal received from the controller 28 (shown in FIG. 1). In the example given the signal generator 66 is a sinusoidal signal generator for generating the signal at a frequency of F_1. The signal is applied to the signal amplifier 68, which amplifies the signal before applying the signal to the coil 38 of the head 30. The signal provided by the generator 66 is also applied to a signal delay 70. The delay is sufficient to take into account the time it takes for a specific part of the tape to move from the head 30 to the head 32. The delayed signal output from delay 70 is applied to a frequency shifter 72 shown in the example as a signal multiplier for multiplying the frequency by a factor of two. The frequency shifted signal is then applied to the amplifier 74 which in turn applies its output to the coil 50 of the head 32. As shown in FIG. 5, numbering the elements 54 and slots 52 consecutively from one end of the head 32 to the other end, the resulting composite signal pattern recorded on the tape is a series of well defined strips of alternating signal pattern 62 and signal pattern 64. Each strip will have its own center line which can define the center line of each track, or the common edge between adjacent strips of patterns 62 and 64 can be used to define the center line of the tracks.

For example, as shown in FIG. 7, the center line of each track is defined by the common edge between adjacent strips of pattern 62 and 64 as indicated by the various positions of a read head 76 as it is moved across the width of the tape as the portion of the tape containing the signal pattern is moved over the read head. The length of the read head extending perpendicular to the direction tape is substantially equal to the width of one track. In this manner where head 32 includes a total of six slots 52 and six recording elements 54, eleven tracks will be defined as shown. Obviously, this number can vary by using a different number of slots and recording elements. The center line of each track can easily be sensed when the frequency output of the read head 76 as it reads the portion of the pattern contains both frequencies F_1 and F_2 of equal amplitude. Thus, by sensing the amplitude of the output signal of the read head at these two frequencies a control system can be easily con-

structed to control the position of the head based on comparison of these two amplitudes. Alternatively, as shown in FIG. 8 the center line of each track is defined by each strip of pattern 62 and pattern 64. In this manner the number of tracks will equal the number of slots 52 plus the number of recording elements 54 so that in the example given, this will result in twelve tracks. The center line of each track can easily be sensed when the frequency output of the read head is a maximum at the frequency F_1 and a minimum at the frequency F_2, or a minimum at the frequency F_1 and a maximum at the frequency F_2.

The two signal patterns shown in FIGS. 7 and 8 differ as to frequency. The two signals can vary as to phase as exemplified in FIGS. 9 and 10 which show the preferred signal pattern. More specifically, the two signals, identified by the patterns 78 and 80 respectively, applied by the respective heads 30 and 32, can be identical series of pulses but applied to the portion of the tape slightly out of phase with one another. This can easily be accomplished as shown in FIG. 10, wherein a signal generator 82 is adapted to generate a series of pulses. The output of the generator 82 is applied to a first delay 84 before being applied to the amplifier 86. The output of the latter is applied to the coil 38 of the head 30 as the portion of the tape receiving the signal pattern is moved over the head 30. The output of the generator 82 is also applied to a second signal delay 88 which provides sufficient delay to take into account the time it takes for a specific point on the tape to move from the head 30 to the head 32, and can be adjusted to provide the desired phase delay. The amount of phase delay is at least in part dependent on detection system used to detect the signal patterns and provide information regarding the position of the center line of each track. As shown in FIG. 9 the center line of the track is aligned with the center line of the read head 76 when the center line of the latter is aligned with the common edge between adjacent strips of the two signal patterns provided by the two heads 30 and 32. The resulting timing diagram of a pulse provided to the two heads is shown in FIG. 10 where the two are out of phase with one another as shown.

In this arrangement the read head detects the two adjacent signal patterns as shown in FIG. 11, where the detected signal pattern shown represents an alignment of the reading head with the track. For each positive transition of each pulse of the write signal provided by the heads 30 and 32, the output of the read amplifier 92 is a pulse of short duration indicated at P_1 (for the positive transition of the pulse provided by head 30) and P_2 (for the positive transition of the pulse provided by head 32). Similarly, for each negative transition of each pulse of the write signal provided by the heads 30 and 32, the output of the read amplifier 92 is a pulse of negative amplitude indicated at $-P_1$ (for the negative transition of the pulse provided by the head 30) and $-P_2$ (for the negative transition of the pulse provided by the head 32). As shown in FIG. 12, mistracking can easily be detected where FIG. 12*a* shows proper tracking, while FIGS. 12*b* and 12*c* show tracking off in the respective directions of the signal pattern provided by the heads 30 and 32. More specifically, as shown in FIG. 12*b* where the read head is positioned off track so as to detect more of the signal pattern provided by the head 30 than that provided by the head 32, the amplitude of the pulse provided by the head 30 will be greater than the amplitude of the pulse provided by the head 32. Accordingly, the pulse outputs P_1 and $-P_1$ will be of greater amplitude than the amplitudes of the pulse outputs of P_2 and $-P_2$. As shown in FIG. 12*c*, the result is opposite when the read head is misaligned so as to detect more of the signal pattern provided by the head 32 than that provided by the head 30. In the latter case, the amplitude of the pulses P_1 and $-P_1$ will be less than the amplitude of the pulses P_2 and $-P_2$. By controlling the position of the read head based on the relative amplitudes of P_1 and P_2 (and $-P_1$ and $-P_2$) the read head can be servo controlled so as to track the center line of the recording track having a center line defined by the common edge between the strips of adjacent signal patterns recorded by the two write heads 30 and 32.

Other signal patterns that can be used are shown in the remaining Figs. The composite signal pattern can be formed by providing a DC erase signal to one of the coils 38 or 50 so that recorded strips of erased portions of the tape are disposed between a recorded signal pattern provided from the other coil. Where the first coil 38 of head 30 is provided for example with a sinusoidal signal, the second coil 50 is provided with a DC signal so as to erase the portions of the tape moving over the recording elements 54. The resulting signal pattern is shown in FIG. 13*a*, with the track center lines being defined by either detecting the sinusoidal signal at its maximum peak amplitude (E_o) and its zero value, or at the common edge between adjacent strips of recorded information where the peak amplitude is $E_o/2$ as shown in FIG. 13*b*.

In FIG. 14 the pattern shown is provided by recording the same sinusoidal signal of finite duration with both heads 30 and 32, but delaying one signal until the other signal has been recorded so that on the tape the second signal starts at the position where the first signal ends. This can be accomplished with the writing device shown in FIG. 15, wherein the signal generator 94 provides a sinusoidal signal for a finite period. The signal is applied to the delay 96 before being applied to the amplifier 98, whereupon the signal is in turn applied to the coil 38. The signal output of the generator 94 is also applied to the delay 100, which in turn provides sufficient delay to allow the signal to be recorded by the head 30 and to take into account the amount of time it takes the tape to move from head 30 to head 32. The output of delay 100 is applied to amplifier 102, which in turn applies its output to the coil 50. When the read head is aligned with the common edge between adjacent strips of recorded signals of the two signal patterns, the two signals will be of equal amplitude as shown in FIG. 14. If however, the read head 76 is not properly aligned the amplitude of the signal will be greater for one signal than the other as illustrated in FIG. 15*b*.

In a manner well known in the art, the servo signals are prerecorded at specific intervals along the tape with data being storable in the respective tracks between the servo signals without erasing the servo signals. In this regard each tape drive can include a disabling device for disabling the write portion of the magnetic head when the read portion senses the servo signals so that the latter will not be erased from the tape as is well known.

In all of the arrangements shown the difference between the two types of signals recorded by the write heads 30 and 32 can be used to control the position of a single read head in a manner well known in the art. Thus, the specific detection schemes are not described

in detail. For example, a detector for tracking a center line up or down is provided in tape drives such as the one sold by Irwin Magnetics of Ann Arbor, Mich.

The foregoing therefore provides an improved technique of simultaneously recording a pattern of servo signals for each track of a multi-track magnetic recording tape in a predetermined period of time as a function of tape speed and tape length and irrespective of the number of channels. The apparatus shown in FIGS. 3 and 4 make the technique easy. The time necessary to record the signals is significantly less than that employed by the prior art techniques. For example, where it may of taken one hour to record the servo signals, the same tape can be recorded in approximately 80 seconds.

Since certain changes may be made in the above apparatus and process without departing form the scope of the present invention herein involved, it is intended that all matter contained in the above description or shown in the accompanying drawing shall be interpreted in an illustrative and not in a limiting sense.

What is claimed is:

1. Apparatus for prerecording track positioning signals on a magnetic recording medium so as to accurately and simultaneously predefine a plurality of space apart recording tracks on said recording medium across the recording width of said medium, said apparatus comprising:

- magnetic head means for simultaneously writing a track positioning signal pattern across the recording width of said magnetic recording medium so as to simultaneously define the positions of said tracks on said medium as a function of the locations of said signals on said medium, said magnetic head means comprising (a) a first write head for recording a first signal pattern on said recording medium, and (b) a second write head, spaced from first write head, for recording a second signal pattern on said recording medium recorded over portions of said first signal pattern so that said first and second signal patterns combine to create said track positioning signal pattern of n alternating steps of said first and second signal patterns so as to define at least n-1 of said recording tracks;
- means for moving said magnetic recording medium relative to said first and second write heads so that said track positioning signal pattern is recorded on said medium; and
- means, coupled to said first and second write heads, for generating said first and second signal patterns as said recording medium is moved relative to said magnetic head means.

2. Apparatus according to claim 1, wherein said first write head is sized to extend and record the first signal pattern substantially across the recording width of said recording medium.

3. Apparatus according to claim 2, wherein said second write head is sized to extend and record the second signal pattern at predetermined and discrete locations across the recording width of the recording medium so that said second signal pattern is recorded as strips over said first signal pattern with said first signal pattern disposed between adjacent strips.

4. Apparatus according to claim 3, wherein said second write head includes a plurality of spaced-apart write head elements precisely spaced from one another by respective gaps of predetermined dimensions for recording said second signal pattern at said discrete locations where said write head elements record on said medium.

5. Apparatus according to claim 4, wherein said means for generating said first and second signal patterns includes a first signal generating means, coupled to said first write head, for generating a first signal representative of said first signal pattern, and second signal generating means, coupled to said second write head, for generating a second signal representative of said second signal pattern.

6. Apparatus according to claim 5, wherein said first signal is a first periodically varying signal and said second signal is a second identical periodically varying signal but out of phase with said first periodically varying signal so that the position of each of said tracks is defined by the signal phase difference between each strip of said recording medium defined by the recorded second periodically varying signal and the first periodically varying signal of said first signal pattern recorded between adjacent strips.

7. Apparatus according to claim 6, wherein the center line of each of said tracks is defined by a corresponding common edge between each of said strips of said recording medium defined by the recorded second periodically varying signal and the first periodically varying signal of said first signal pattern recorded between adjacent strips.

8. Apparatus according to claim 6, wherein said first signal is a first series of pulses and said second signal is a second series of pulses identical to but out of phase with said first series of pulses.

9. Apparatus according to claim 6, wherein said first signal is a first sinusoidal signal of a predetermined frequency and said second signal is a sinusoidal signal of identical frequency but out of phase with said first sinusoidal signal.

10. Apparatus according to claim 5, wherein said first signal is a first periodically varying signal of a first frequency and said second signal is a second periodically varying signal of a second frequency different from said first frequency so that the position of each of said tracks is defined by the detected frequency difference between each strip of said recording medium defined by the recorded second periodically varying signal and the first periodically varying signal of said first signal pattern recorded between adjacent strips.

11. Apparatus according to claim 10, wherein the center line of each of said tracks is defined by a corresponding common edge between each of said strips of said recording medium defined by the recorded second periodically varying signal and the first periodically varying signal of said first signal pattern recorded between adjacent strips.

12. Apparatus according to claim 10, wherein the center line of each of said tracks is defined by each of the center lines of each of said strips of said recording medium defined by the recorded second periodically varying signal and the center lines of the portions of said recording medium recorded with said first periodically varying signal between adjacent strips.

13. Apparatus according to claim 5, wherein one of said first and second signals is a periodically varying signal of a constant frequency and the other of said first and second signals is a constant amplitude signal so that the position of each of said tracks is defined by the detected amplitude of said periodically varying signal.

14. Apparatus according to claim 13, wherein the center line of each of said tracks is defined by a corre-

sponding common edge between each of said strips of said recording medium defined by the recorded periodically varying signal and the constant amplitude signal.

15. Apparatus according to claim 14, wherein the center line of each of said tracks is defined by the detection of the maximum amplitude of said periodically varying signal.

16. Apparatus according to claim 14, wherein the center line of each of said tracks is defined by the detection of the maximum amount of said constant amplitude signal.

17. Apparatus according to claim 16, wherein said constant amplitude signal is a DC signal of an amplitude so as to erase the corresponding portions of said recording medium on which said constant amplitude is recorded.

18. A method of prerecording track positioning signals on a magnetic recording medium so as to accurately and simultaneously predefine a plurality of spaced apart recording tracks on said recording medium across the recording width of said medium, said method comprising the steps of:

simultaneously writing a track positioning signal pattern across the recording width of said magnetic recording medium so as to simultaneously define the positions of said tracks on said medium as a function of the locations of said signals on said medium, said step of writing comprising (a) recording a first signal pattern on said recording medium, and (b) recording a second signal pattern on said recording medium over portions o f the first signal pattern so that said first and second signal patterns combine to create said track positioning signal pattern of n alternating strips of said first and second signal patterns so as to define at least n-1 of said recording tracks;

moving said magnetic recording medium so that said track positioning signal pattern is recorded on said medium; and

generating said first and second signal patterns as said recording medium is moved.

19. A method according to claim 18, wherein said step of recording said first signal pattern includes the step of recording said first signal pattern substantially across the recording width of said recording medium.

20. A method according to claim 19, wherein said step of recording said second signal pattern includes the step of recording said second signal pattern at predetermined and discrete locations across the recording width of the recording medium so that said second signal pattern is recorded as strips over said first signal pattern with said first signal pattern disposed between adjacent strips.

21. A method according to claim 20, wherein said second write head includes a plurality of spaced-apart write head elements precisely spaced from one another by respective gaps of predetermined dimensions for recording said second signal pattern at said discrete locations where said write head elements record on said medium.

22. A method according to claim 21, wherein said step of generating said first and second signal patterns includes the step of generating a first signal representative of said first signal pattern, and generating a second signal representative of said second signal pattern.

23. A method according to claim 22, wherein said step of generating said first and second signal patterns includes the steps of generating said first signal as a first periodically varying signal and said second signal as a second identical periodically varying signal but out of phase with said first periodically varying signal so that the position of each of said tracks is defined by the signal phase difference between each strip of said recording medium defined by the recorded second periodically varying signal and the first periodically varying signal of said first signal pattern recorded between adjacent strips.

24. A method according to claim 23, wherein the center line of each of said tracks is defined by a corresponding common edge between each of said strips of said recording medium defined by the recorded second periodically varying signal and the first periodically varying signal of said first signal pattern recorded between adjacent strips.

25. A method according to claim 23, wherein said step of generating said first and second signal patterns includes the steps of generating said first signal as a first series of pulses and said second signal as a second series of pulses identical to but out of phase with said first series of pulses.

26. A method according to claim 23, wherein said step of generating said first and second signal patterns includes the steps of generating said first signal as a first sinusoidal signal of a predetermined frequency and said second signal as a sinusoidal signal of identical frequency but out of phase with said first sinusoidal signal.

27. A method according to claim 22, wherein said step of generating said first and second signal patterns includes the steps of generating said first signal as a first periodically varying signal of a first frequency and said second signal as a second periodically varying signal of a second frequency different from said first frequency so that the position of each of said tracks is defined by the detected frequency difference between each strip of said recording medium defined by the recorded second periodically varying signal and the first periodically varying signal of said first signal pattern recorded between adjacent strips.

28. A method according to claim 27, wherein the center line of each of said tracks is defined by a corresponding common edge between each of said strips of said recording medium defined by the recorded second periodically varying signal and the first periodically varying signal of said first signal pattern recorded between adjacent strips.

29. A method according to claim 28, wherein the center line of each of said tracks is defined by each of the center lines of each of said strips of said recording medium defined by the recorded second periodically varying signal and the center lines of the portions of said recording medium recorded with said first periodically varying signal between adjacent strips.

30. A method according to claim 22, wherein said step of generating said first and second signal patterns includes the step of generating one of said first and second signals as a periodically varying signal of a constant frequency and the other of said first and second signals as a constant amplitude signal so that the position of each of said tracks is defined by the detected amplitude of said periodically varying signal.

31. A method according to claim 30, wherein the center line of each of said tracks is defined by a corresponding common edge between each of said strips of said recording medium defined by the recorded periodically varying signal and the constant amplitude signal.

32. A method according to claim 31, wherein the center line of each of said tracks is defined by the detection of the maximum amplitude of said periodically varying signal.

33. A method according to claim 31, wherein the center line of each of said tracks is defined by the detection of the maximum amount of said constant amplitude signal.

34. A method according to claim 33, wherein said constant amplitude signal is a DC signal of an amplitude so as to erase the corresponding portions of said recording medium on which said constant amplitude is recorded.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 4,996,609

DATED : February 26, 1991

INVENTOR(S) : Kyriacos Joannou

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 9:

Claim 1, line 41, delete "steps" and insert therefor -- strips --; and

Column 11:

Claim 18, line 31, delete "o f" and insert therefor -- of --.

Signed and Sealed this

Eighteenth Day of August, 1992

Attest:

DOUGLAS B. COMER

Attesting Officer

Acting Commissioner of Patents and Trademarks

US 20050168869A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2005/0168869 A1**

Dugas et al. (43) **Pub. Date: Aug. 4, 2005**

(54) **APPARATUSES AND METHODS FOR PRE-ERASING DURING MANUFACTURE OF MAGNETIC TAPE**

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(21) Appl. No.: **10/768,719**

(22) Filed: **Jan. 30, 2004**

Publication Classification

(51) **Int. Cl.**[7] **G11B 5/127**

(52) **U.S. Cl.** **360/118**

(57) **ABSTRACT**

The present invention relates to direct current ("DC") pre-erasing servo channels of a magnetic tape prior to writing servo data in a servo channel. The present invention particularly relates to those servo recordings which were written with a uni-polar current waveform. The DC pre-erase is performed using a uni-polar direct current of a polarity that is opposite to the polarity of the direct current used to write the servo data. This pre-erase may be done with one or more heads. Also, as will be described, the pre-erase of a servo channel and writing to a servo channel may be done by making two passes over a single head or by using two or more heads to perform both steps. Also, it is within the scope of the present invention to have the heads mounted on a single mount or have the heads on separate mounts and on separate tape decks.

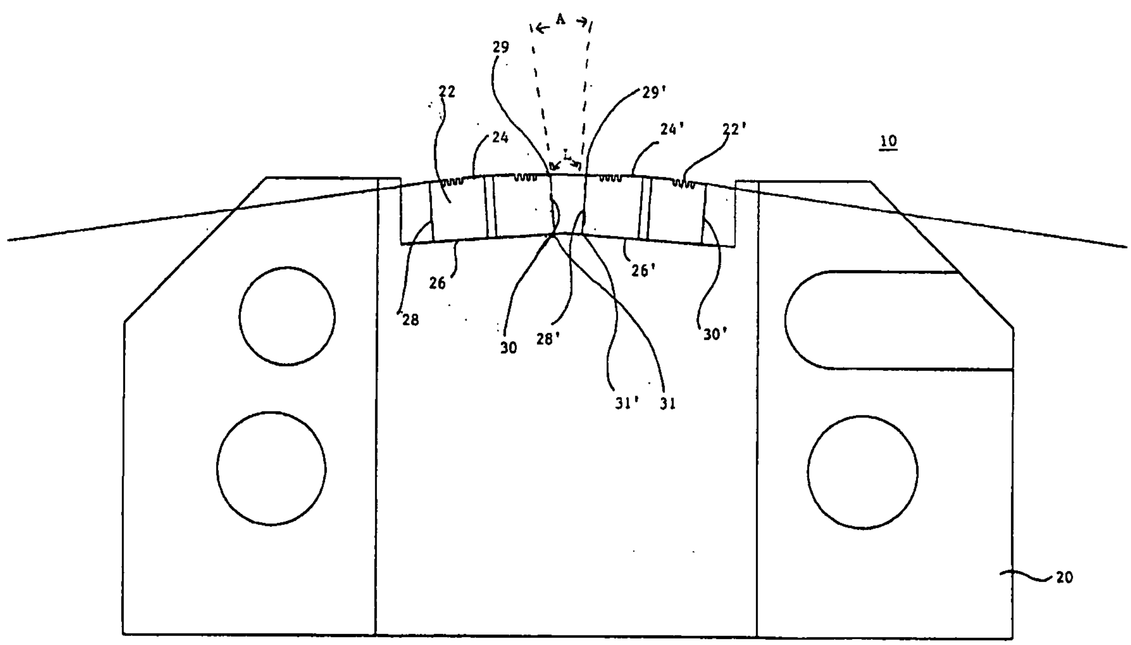
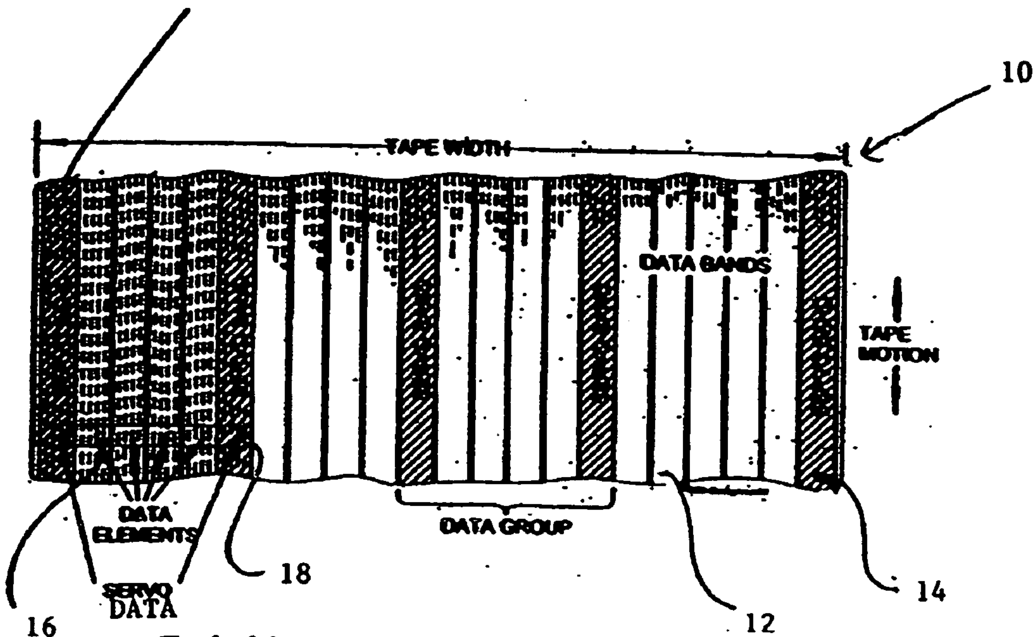


Figure 1



Typical Servoed Tape organization

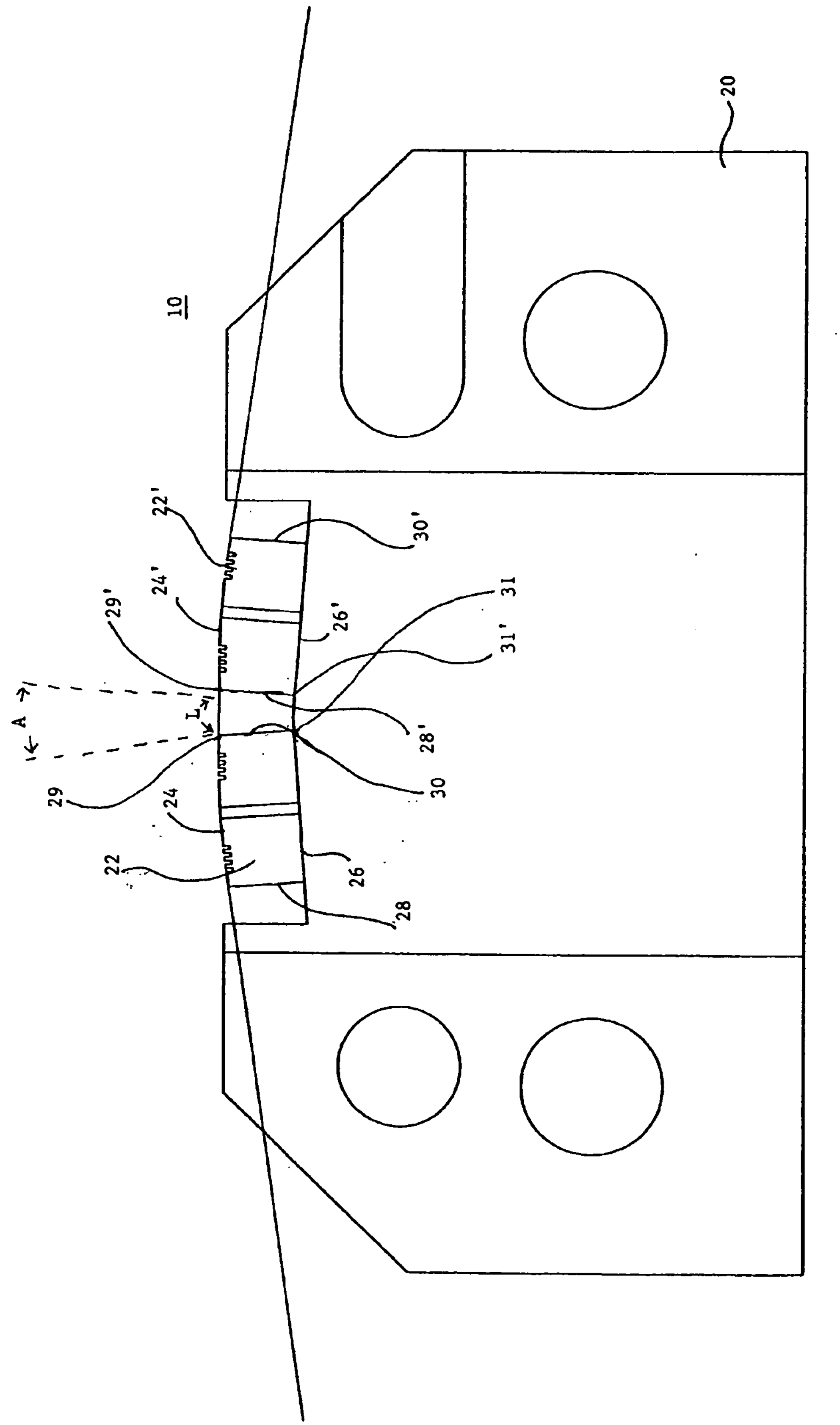


Figure 2

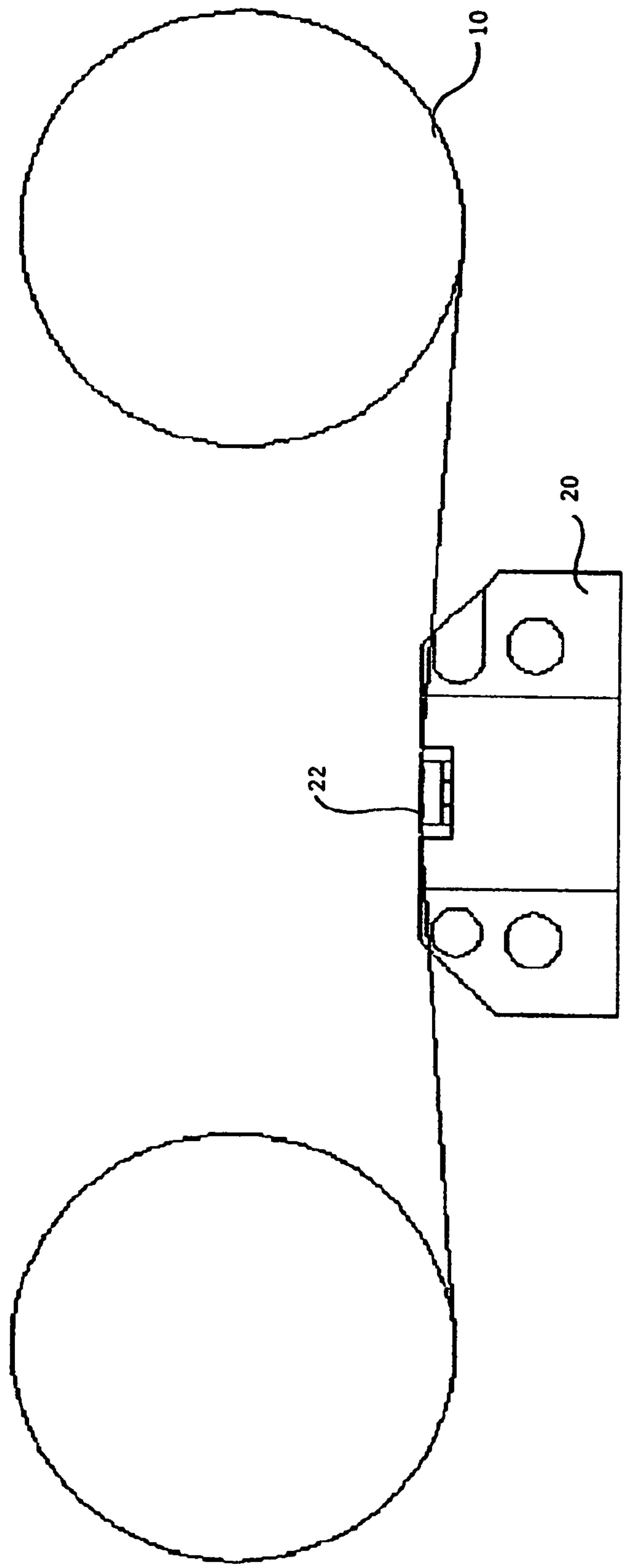


Figure 3

Figure 4

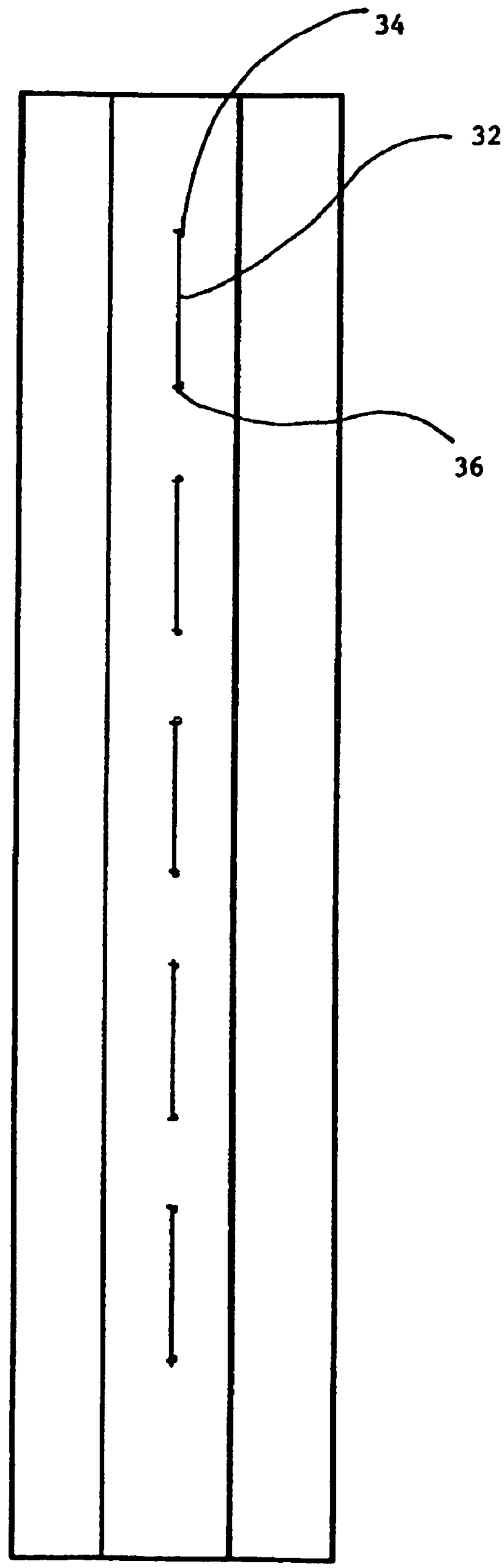


Figure 5

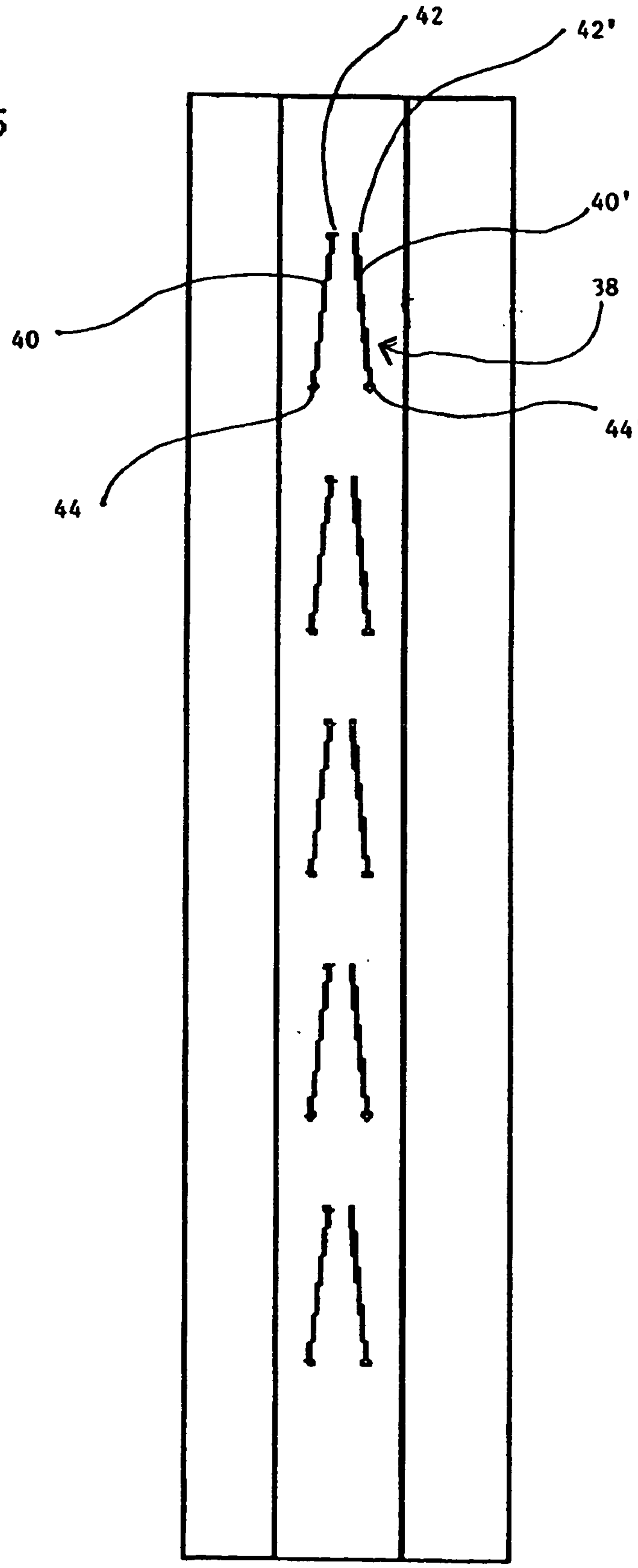
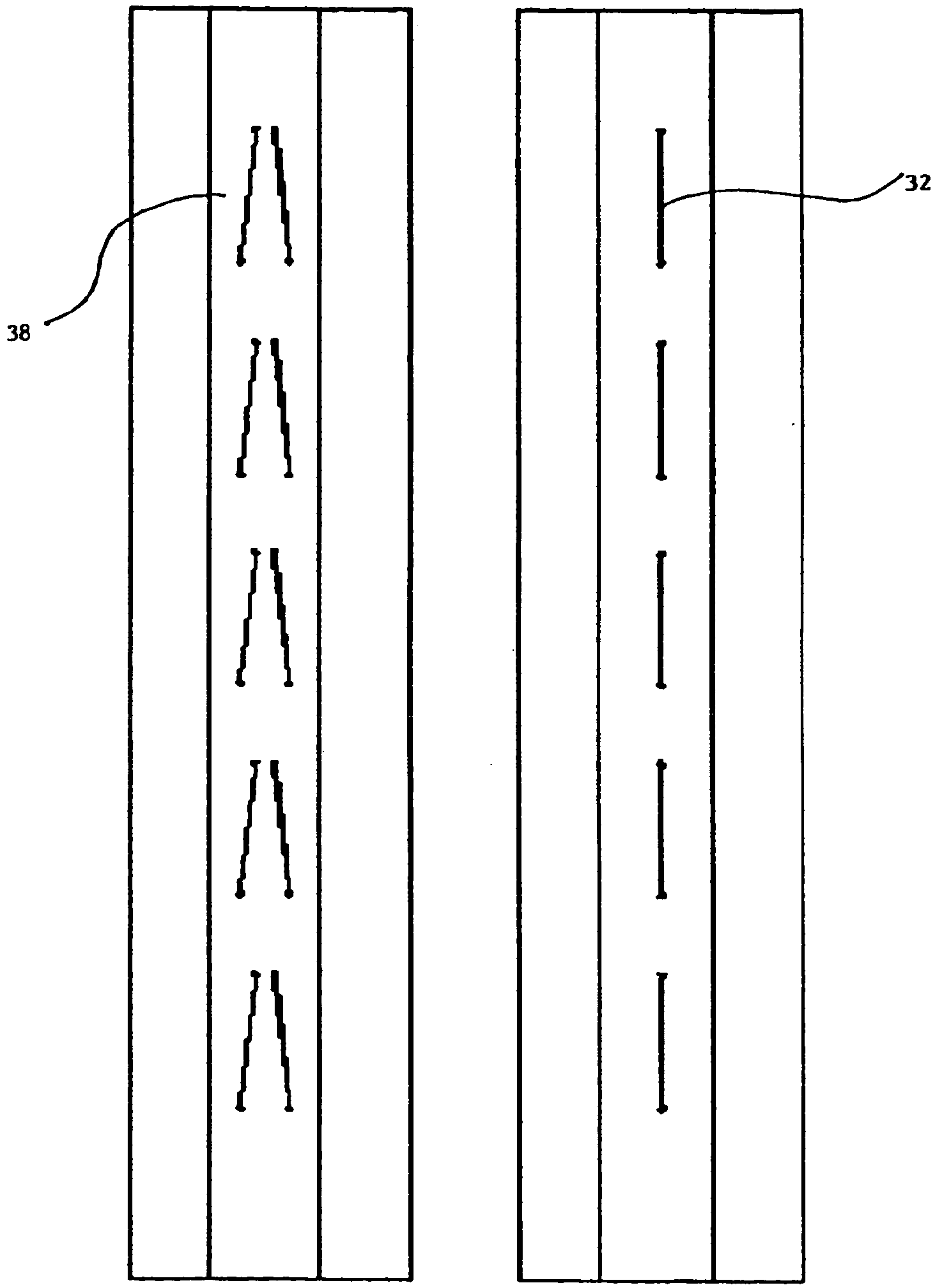


Figure 6



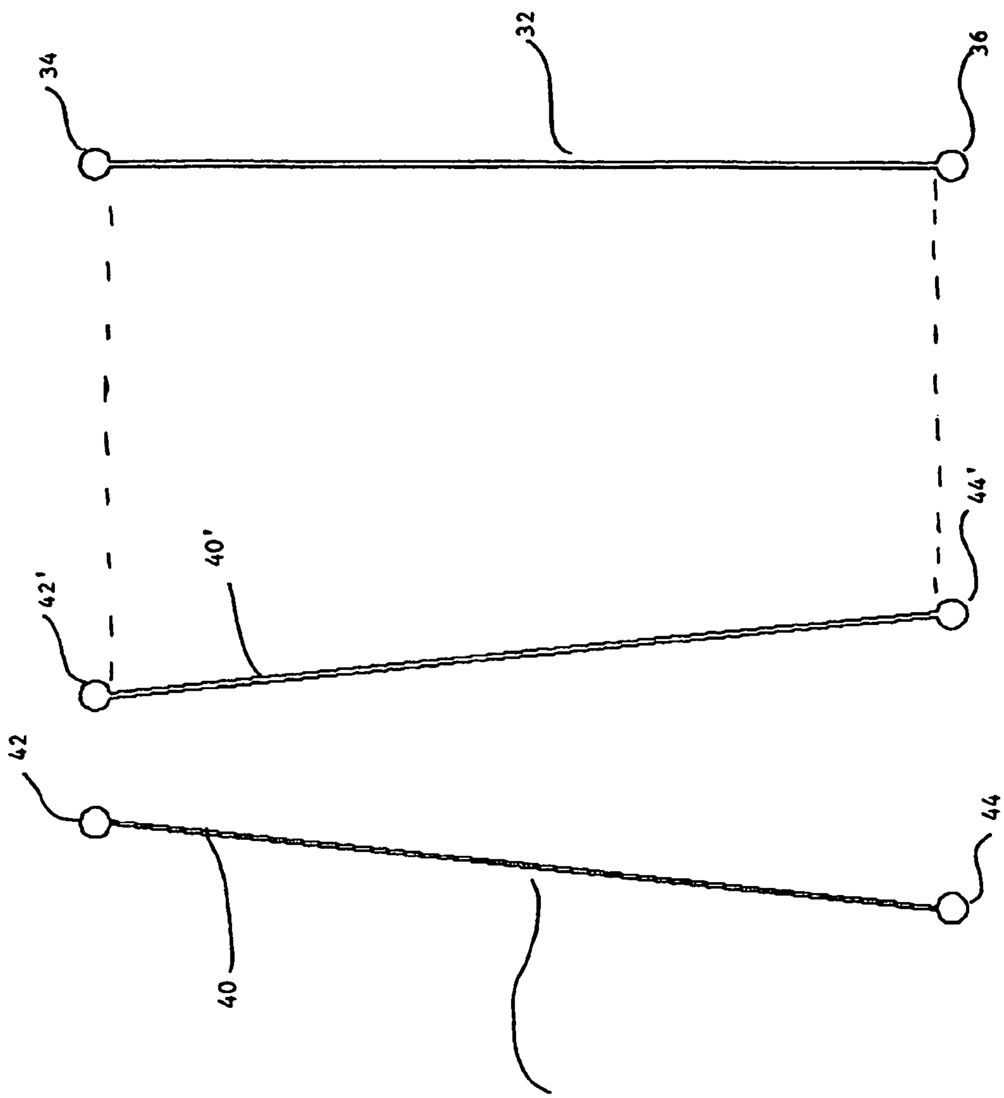


Figure 7

Figure 8A

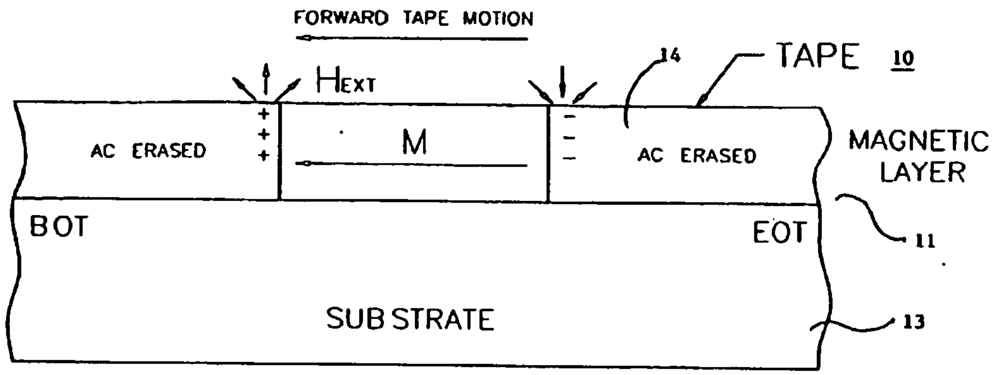


Figure 8B

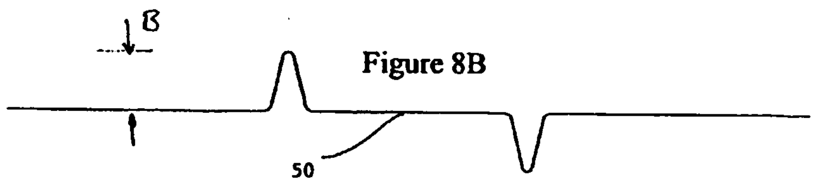


Figure 8C

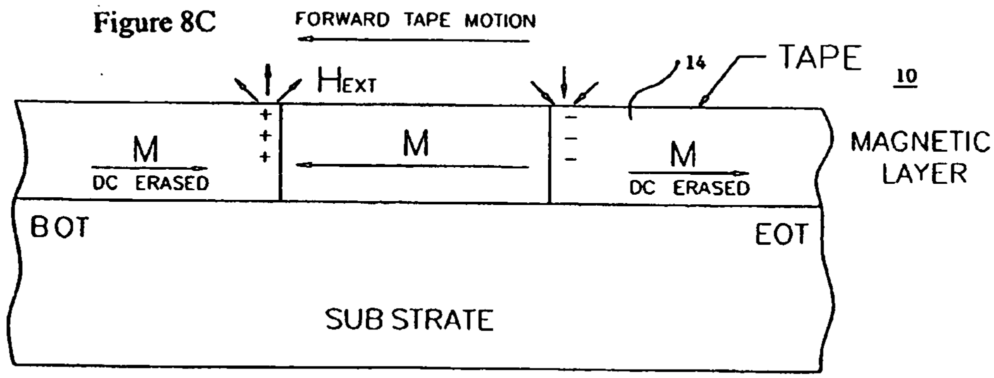


Figure 8D

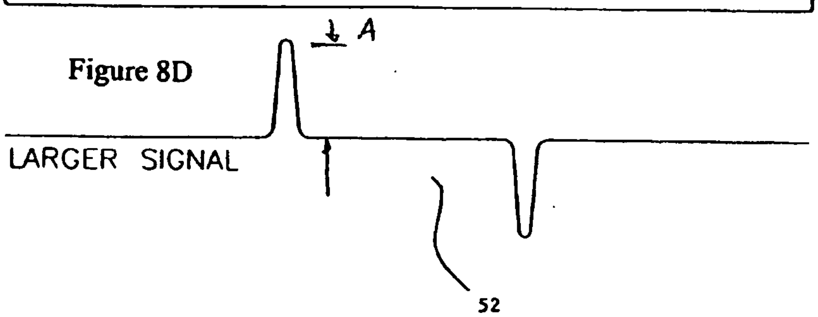


Figure 9A

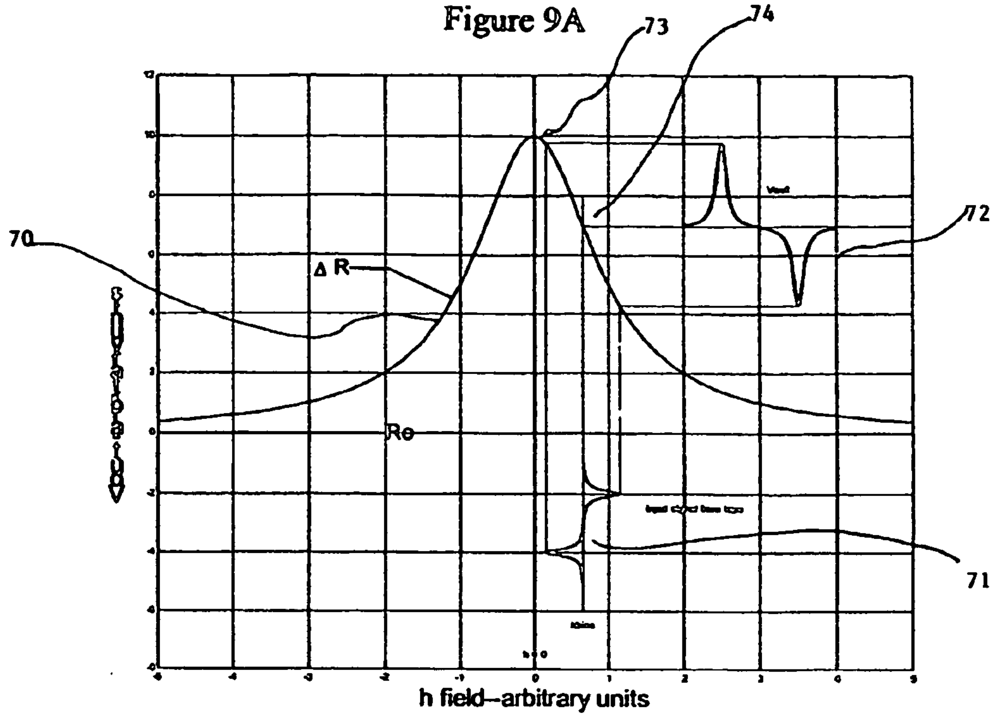


Figure 9B

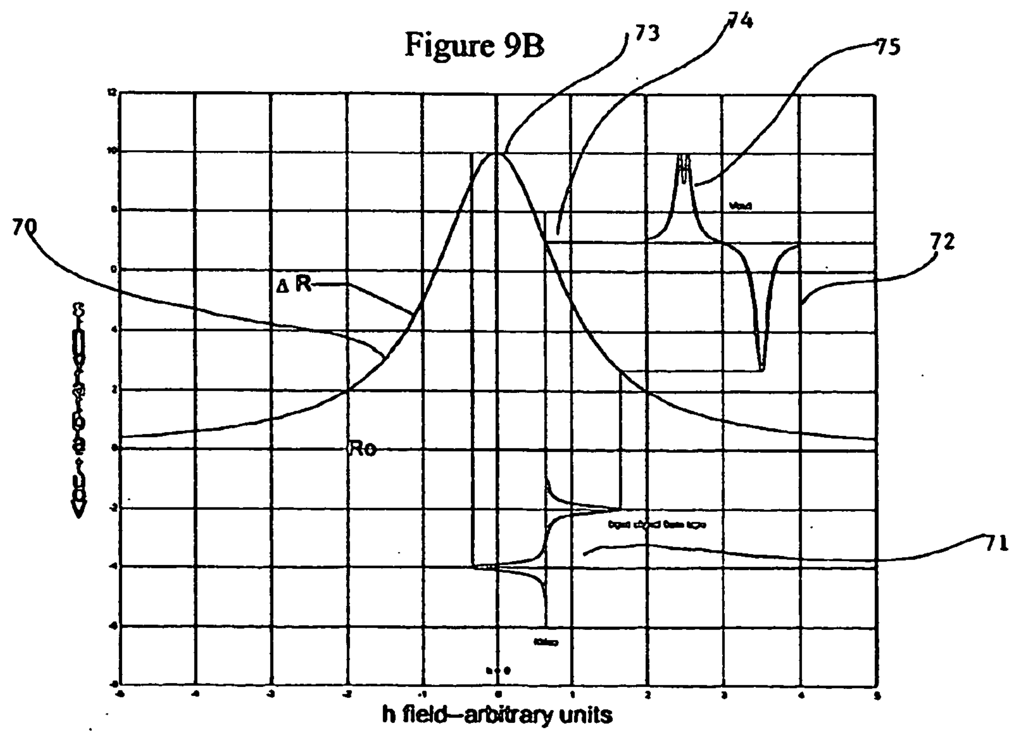


Figure 10

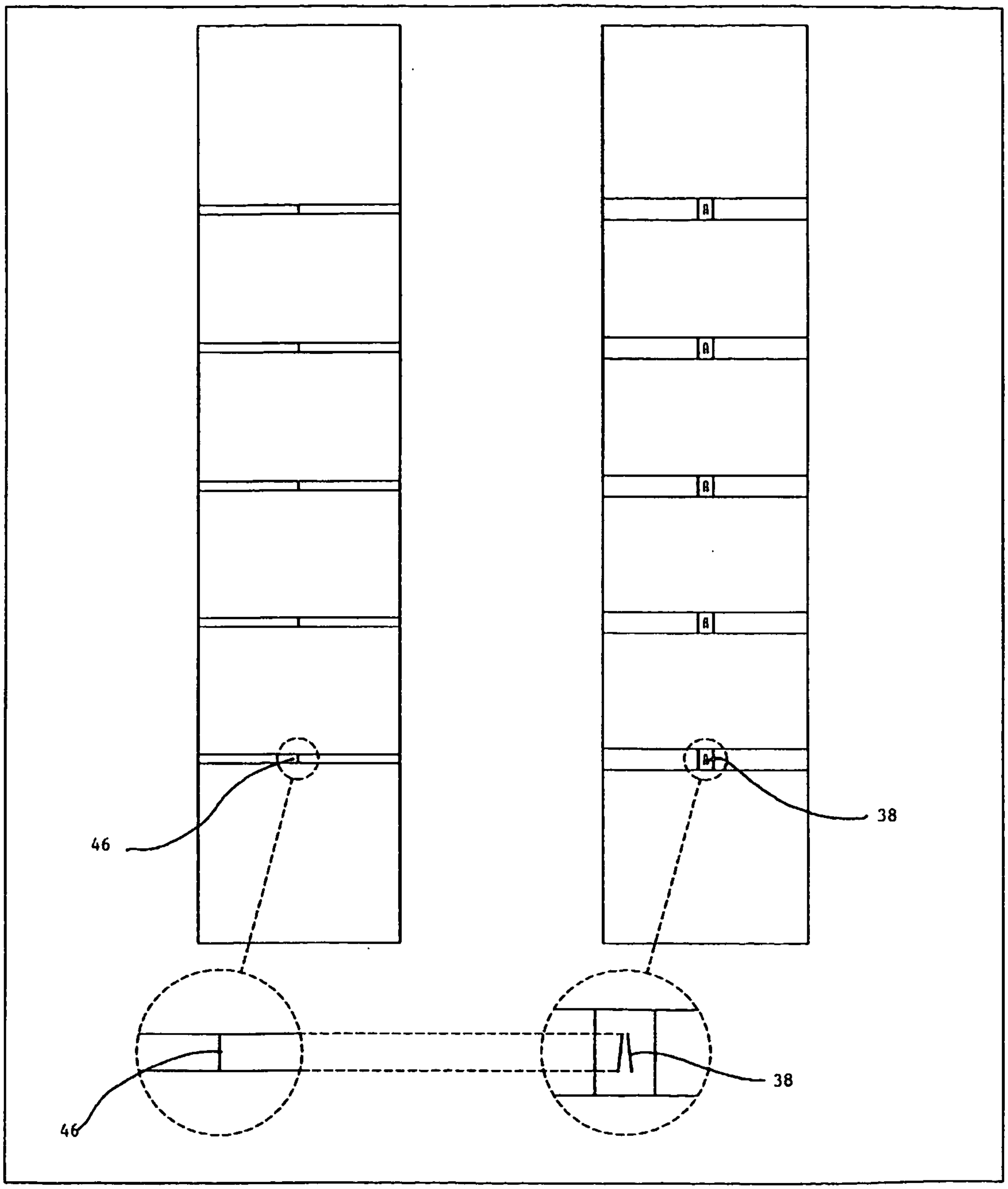
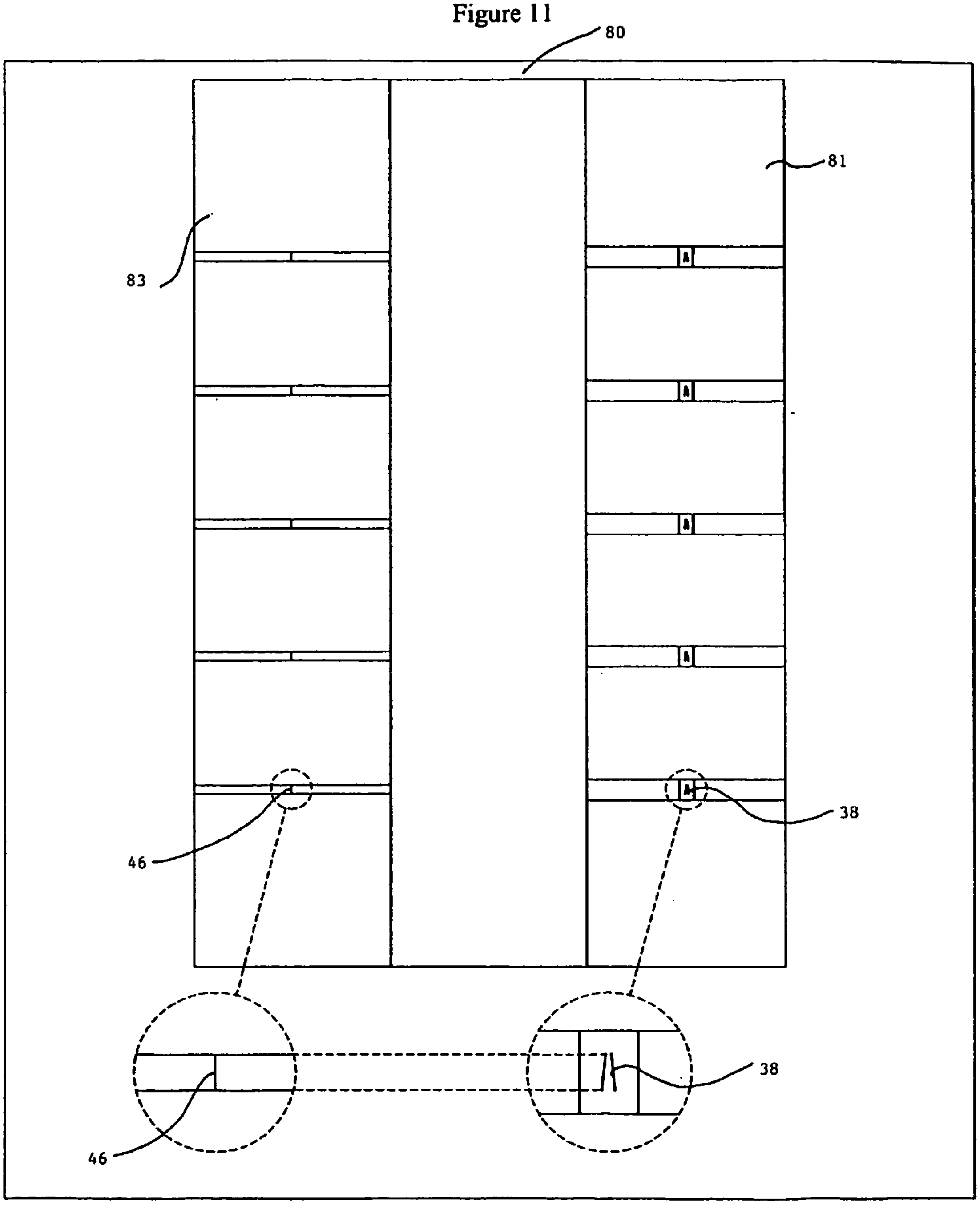


Figure 11



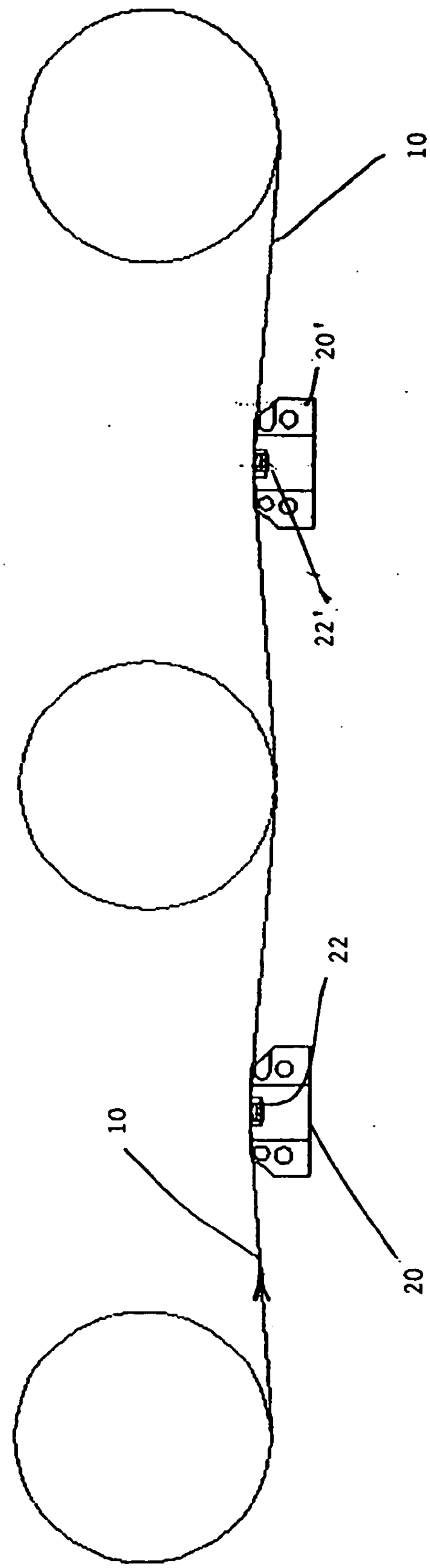


Figure 12

APPARATUSES AND METHODS FOR PRE-ERASING DURING MANUFACTURE OF MAGNETIC TAPE

TECHNICAL FIELD

[0001] The present invention relates to apparatuses and methods for use in the manufacture of magnetic tape. In particular, the present invention relates to apparatuses and methods for pre-erasing a servo channel of a magnetic tape.

BACKGROUND OF THE INVENTION

[0002] Magnetic tape as a data storage medium requires the ability to effectively write and read data to data tracks of the magnetic tape; many such data tracks typically extend linearly along the length of tape and, in part, define tape data storage density. In addition, for providing a controlled movement of tape reading and/or writing heads with respect to the data track, servo tracks, which also extend linearly along the length of tape are commonly used. Servo tracks are typically written in such a way as to span the tape in an efficient manner that maximizes the number of data tracks and minimizes the number of servo tracks for a given tape system.

[0003] A servo track contains servo data and is read by a servo read head. This information is used to determine the relative position of the servo read head with respect to the magnetic media in a translating direction (i.e., movement across the width of the tape). This is also called the cross track direction. To improve positioning of the tape reading and/or writing heads on a magnetic tape, apparatuses and methods of manufacture to create a servo channel that enables the servo data to be read more effectively would be helpful. The present invention addresses apparatuses and methods to improve a servo control system.

BRIEF SUMMARY OF THE INVENTION

[0004] The present invention relates to direct current ("DC") pre-erasing servo channels of a magnetic tape prior to writing servo data in a servo channel. The present invention particularly relates to those servo recordings which were written with a uni-polar current waveform. The DC pre-erase is performed using a uni-polar direct current of a polarity that is opposite to the polarity of the direct current used to write the servo data. This pre-erase may be done with one or more heads. Also, as will be described, the pre-erase of a servo channel and writing to a servo channel may be done by making two passes over a single head or by using two or more heads to perform both steps. Also, it is within the scope of the present invention to have the heads mounted on a single mount or have the heads on separate mounts and on separate tape decks.

[0005] In one embodiment, the present invention relates to a magnetic tape comprising a substrate and a magnetic layer, the magnetic tape having at least one direct current pre-erased servo channel that includes servo data.

[0006] In another embodiment, the present invention relates to a magnetic tape having at least one servo channel that is direct current pre-erased and has servo data written in the at least one servo channel.

[0007] The magnetic tape is made by a method comprising writing a servo pattern using a uni-polar direct current of a particular pulse train. Prior to writing a servo pattern, erasing the servo channel of the magnetic tape by applying a direct current of a substantially opposite polarity to that of the servo write current pulse sequence.

[0008] The present invention also relates to an apparatus for use in pre-erasing magnetic tape, comprising a housing supporting at least two heads, wherein at least one of the two heads includes a gap pattern to direct current pre-erase the servo channels on the magnetic tape, wherein the other of the two heads includes a gap pattern for recording the servo channel that is written after the pre-erase has been first recorded.

[0009] The present invention further relates to an apparatus for use in pre-erasing magnetic tape, comprising a compound substrate having at least a first substrate and a second substrate, wherein the first substrate includes at least one servo pattern and the second substrate includes at least one direct current pre-erase pattern.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] **FIG. 1** shows a typical servo track and data track organization on the tape.

[0011] **FIG. 2** is a schematic drawing of one embodiment of the present invention showing a housing supporting two heads with magnetic tape extending over the heads, where one of the heads is used to pre-erase with direct current the servo channels of a magnetic tape and the other is used to record the servo pattern onto the pre-erase servo channels.

[0012] **FIG. 3** is a schematic drawing of one embodiment of the present invention showing a housing supporting one head with the magnetic tape extending over the head, where the head is used to pre-erase with direct current the servo channels of a magnetic tape.

[0013] **FIG. 4** shows an exemplary servo erase gap pattern on the surface of a surface film head.

[0014] **FIG. 5** shows an exemplary servo gap pattern on the surface of a surface film head that may be used to write a servo pattern in the servo channel on a magnetic tape.

[0015] **FIG. 6** shows a two head configuration in which one head has a gap pattern that would be used to DC pre-erase the servo channel and the other head has a timing based servo gap pattern that would write a timing based pattern onto the servo channel on a magnetic tape.

[0016] **FIG. 7** shows a close-up of the patterns shown in **FIG. 6**. Note that the patterns are matched so that the erase track width is substantially the same as the servo track width.

[0017] **FIGS. 8A-8B** show a portion of a magnetic layer and substrate of a magnetic tape and a theoretical output signal from a servo pattern on a magnetic tape in which the tape and servo channel have been AC erased.

[0018] **FIGS. 8C-8D** show a portion of a magnetic layer and substrate of a magnetic tape and a theoretical output signal from a servo pattern on a magnetic tape in which the servo channel has been DC erased prior to recording the servo signal.

[0019] **FIG. 9A and 9B** show theoretical waveforms for relating the magnetoresistive (MR) response curve of the

head, an input field from the magnetic tape, and an output voltage signal from the MR head element.

[0020] **FIG. 10** shows a two head configuration in which one head is a ferrite MIG head having a gap pattern that would be used to DC pre-erase the servo channel and the other head is a surface thin film head using the low inductance, ferrite sub-gap substrate having a timing based servo gap pattern that would write a timing based pattern onto the servo channel on a magnetic tape.

[0021] **FIG. 11** shows an embodiment of the present invention using a compound substrate.

[0022] **FIG. 12** is a schematic drawing of one embodiment of the present invention showing a first housing supporting one head with the magnetic tape extending over the head, where the head is used to pre-erase with direct current the servo channels of a magnetic tape and a second housing supporting one head with magnetic tape extending over the head, where the head is used to write servo data in the servo channel of the magnetic tape.

DETAILED DESCRIPTION

[0023] The present invention relates to apparatuses and methods used in manufacturing magnetic tape. In particular, the present invention relates to manufacture of magnetic tape that includes servo data in one or more servo channels, where one or more servo channels has been pre-erased with a uni-polar signal prior to the servo data being written in a servo channel. Pre-erasing a servo channel with direct current enables the servo read signal representing the uni-polar written servo pattern to be stronger than a servo read signal in a similar servo channel that is not pre-erased. As such, pre-erasing the servo channel during the manufacture and formatting of the magnetic tape will provide benefits by increasing the signal to noise ration of the servo read signal. This in turn can lead to higher areal data storage densities for the magnetic tape. However, it is important to note that the response of a magnetoresistive ("MR") head to this technique may be too strong and result in distortion and non-linear servo read signals. Hence this technique is to be used when the media thickness and M_rt ratio has become smaller in more aggressive higher density products and when using such a technique will not overdrive the MR servo read head. Since the result of this technique is to increase the servo read signal, it is important to not use it if it will send the read head into a non-linear response region. On the other hand, as areal densities are ever increasing and typically accompanying this the M_rt ratio is decreasing, the use of this technique may prove beneficial in certain servo systems as tape thicknesses continue to decrease.

[0024] **FIG. 1** shows a magnetic tape **10** having data bands or data tracks **12** (also, may be referred to as data channels) and servo bands or servo tracks **14** (also may be referred to servo channels). The data tracks **12** would be the portion of tape **10** to which data elements **16** would be written and from which data elements **16** would be read. Similarly, servo tracks **14** would include servo data **18** which are written into the servo track during manufacture of the magnetic tape **10**. This servo data **18** is used by the servo control system to help properly position the read and write heads with respect to the data tracks **12**. The present invention relates to pre-erasing servo tracks **14** with a direct current or uni-polar pre-erase signal prior to writing a uni-polar servo pattern of the opposite polarity in the servo track **14**.

[0025] In the preferred embodiment, only the servo channels **14** of a magnetic tape **10** are pre-erased by applying a uni-polar, direct current erase signal through a precise gap pattern in the head. A uni-polar servo pattern is then written upon the pre-erased servo channel but in the opposite polarity. The servo pattern may be timing based or amplitude based or a combination of both. However, the present invention will typically be used with a time based pattern as timing patterns are typically uni-polar and amplitude patterns are typically bi-polar. On bi-polar current written or recorded servo channels **14**, the technique is less effective in increasing the signal-to-noise ("SNR") of the servo read system.

[0026] In manufacturing magnetic tape **10**, the DC pre-erase and the writing of a servo pattern may be accomplished using two or more heads or using one head. For instance, in one embodiment, a portion of the magnetic tape **10** is first passed over a head to perform a DC erase of servo channels **14** of the magnetic tape **10** and then another head is used to write a servo pattern into the servo channels **14** of the magnetic tape **10**. Alternatively, the same head may be used to perform a DC erase of the servo channels **14** on a magnetic tape **10** and then to write a servo pattern in the servo channels **14** of the magnetic tape **10**. That is, in this embodiment, the magnetic tape **10** is passed over the head to perform a DC erase of the servo channels **14**. A pulse is applied through the pattern in the head to DC erase the servo channels **14** of the magnetic tape **10**. Then, the tape **10** is passed over the head a second time to write a servo pattern into the servo channels **14** of the magnetic tape **10**.

[0027] In one embodiment, two heads are used and are mounted into a housing so that an efficient one pass servo formatting system may be used. This embodiment is shown in **FIG. 2**. However, each head may be separately supported by a separate housing or even a separate tape deck (as shown in **FIG. 12**).

[0028] With reference to **FIGS. 2 and 3**, embodiments of an apparatus for use in DC pre-erasing a servo channel **14** of a magnetic tape **10** will be described. **FIG. 2** shows a housing **20** with magnetic tape **10** extending across the two heads **22, 22'**. As shown in **FIG. 2**, the embodiment includes a housing **20** that supports a first head **22** and a second head **22'**. The heads have a first surface **24, 24'**, a second surface **26, 26'**, a first side surface **28, 28'**, and a second side surface **30, 30'**. The first surface **24, 24'** is in contact with the magnetic tape **10**. The second surface **26, 26'** of the heads is attached to and supported by the housing **20**. In one embodiment, the heads **22, 22'** are mounted to the housing using an epoxy. However, the heads may be mounted using any suitable means.

[0029] The heads **22** and **22'** are disposed side-by-side separated by a predetermined distance L. As shown in **FIG. 2**, in one embodiment, the heads **22** and **22'** are spaced apart approximately 1.0 millimeters ("mm") around the top edge **29, 29'** (i.e., toward the first surface **24**) and spaced apart approximately 0.80 mm at the bottom edge **31, 31'** (i.e., toward the second surface **26**). It will be appreciated that while the distance between the heads is specified, other distances may be used. Similarly, the angle A formed between the two heads may be varied and even flat contours

may be used. While **FIG. 2** shows the heads **22** and **22'** not spaced such that the sides **30, 28'** are parallel to each other, the heads may be spaced in such a manner that the sides **30, 28'** of the first and second heads **22** and **22'** are substantially parallel to each other in the vertical direction as shown.

[0030] Any type of head may be used in the dual head configuration including, but not limited to thin film heads, ferrite based heads, and surface thin film heads. For instance, the first and second heads **22** and **22'** may be heads with low inductance, ferrite sub-gap substrate surface film head structures of the type described in U.S. Pat. No. 6,496,328, which is hereby incorporated by reference in its entirety, a surface thin-film head of the type disclosed in U.S. Pat. No. 6,269,533, which is hereby incorporated by reference in its entirety, or a ferrite metal-in-gap ("MIG") head. Any combination of these types of heads may be used when using two or more head in implementing an embodiment of the present invention. It will be noted that one head will be optimized as an erase head and the other head will be optimized as a servo write head.

[0031] In one embodiment of the dual configuration (as shown in **FIG. 10**), a ferrite MIG head or a surface thin film head with a pattern would be used to perform the DC erase and a surface thin film head using the low inductance, ferrite sub-gap substrate surface film head with a time base servo pattern would be used to write a servo pattern on the servo channel of the magnetic tape. **FIG. 10** shows a ferrite MIG head with a pre-erase gap **46** to perform a DC erase with a surface thin film head having gap for an amplitude or a time based servo pattern for writing to a servo channel **14**. As shown in **FIG. 10**, the width of the pre-erase gap is substantially the same as the width of the servo pattern.

[0032] The housing **20** may be formed from any appropriate material including metal. The housing **20** is milled to position the heads **22, 22'** to the housing. Furthermore, it will be appreciated that while **FIG. 2** shows a housing that includes two heads, a housing having more than two heads is within the scope of the present invention.

[0033] **FIG. 3** shows a housing mount **20** that has a first head **22**. This embodiment may be used when the heads for performing the DC pre-erase on the servo channels **14** and writing the servo patterns on the servo channels **14** are located on different tape decks or this embodiment may be used when the same head is used to perform both the DC erase on one pass and write the servo data **18** on the servo track **14** on a second pass. **FIG. 12** shows a first housing **20** supporting a first head **22** with the magnetic tape **10** extending over the head **22**, where the head is used to pre-erase with direct current the servo channels **14** of a magnetic tape **10** and a second housing **20'** supporting a second head **22'** with magnetic tape **10** extending over the second head **22'**, where the second head **22'** is used to write servo data in the servo channel **14** of the magnetic tape **10**.

[0034] **FIG. 11** shows an alternative embodiment that may be used for more precise pattern combinations than a mechanically assembled dual module head pair. **FIG. 11** shows a compound substrate **80**. As shown in **FIG. 11**, the compound substrate **80** has a first substrate **81** and a second substrate **83**. The first and second substrates **81** and **83** are spaced apart a predetermined distance L by use of a first block **85** to separate the substrates. The first substrate includes a pre-erase gap **46** to DC erase a servo channel and the second substrate includes a servo pattern that is written in the DC pre-erased servo channel. As shown in **FIG. 11**, the pre-erase gap is ideally substantially the same width at the servo pattern. The pre-erase gap may have a slightly larger width than the width of the servo pattern. The first block **85** separating the compound substrate may be formed with ceramic. However, other materials may be used to separate the substrates. The substrates may be joined together using epoxy.

[0035] **FIG. 11** shows a compound substrate **80** having a combination of a surface thin film head (of the type described in U.S. Pat. No. 6,269,533) and a low inductance surface thin film head (of the type described in U.S. Pat. No. 6,496,328). Also, while two substrates are joined together in **FIG. 11**, a compound substrate having more than two substrates is within the scope of the present invention.

[0036] The compound substrate in **FIG. 11** may have all the gaps lithographically printed by a single mask and hence all patterns printed on those sub-gaps will have lithographic precision to the order of 0.1 microns or better. Hence, the compound substrate module may be used for more precise pattern combinations than a mechanically assembled dual module head pair.

[0037] The apparatuses discussed with respect to **FIGS. 2 and 3** may contain various servo patterns where one of the patterns is for performing a DC pre-erase of a servo track **14**. **FIG. 4** shows an exemplary servo erase gap pattern on the surface of a surface film head. While the servo head itself of **FIG. 5** may be used to pre-erase the tape **10** this would require a two pass operation which would be time inefficient. However that would be within the scope of the present invention.

[0038] **FIG. 4** shows an exemplary servo erase gap pattern on the surface of a surface film head. The servo erase gap pattern **32** includes a first termination **34** and a second termination **36**. The terminations **34, 36** may have curved portions. As shown in **FIG. 4**, the terminations **34** and **36** are circular. **FIG. 5** shows an exemplary servo gap pattern on the surface of a surface film head that may be used to write a servo pattern in the servo channel **14** on a magnetic tape **10**. **FIG. 5** shows a servo gap pattern **38** that is time based. The servo gap pattern **38** has a first portion **40** and a second portion **40'**, with each portion **40, 40'** having a first termination **42, 42'** and a second termination **44, 44'**. As with the pattern in **FIG. 4**, the terminations **42, 42', 44, 44'** have curved portions, and as shown, have circular terminations. It will be appreciated that other types servo patterns may be used without departing from the scope of the present invention.

[0039] **FIG. 6** shows a two head configuration in which one head has a gap pattern **32** that would be used to DC pre-erase the servo channel and the other head has a timing based servo gap pattern **38** that would write a timing based pattern onto the servo channel on a magnetic tape **10**. **FIG. 7** shows a close-up of the patterns shown in **FIG. 6**. Note that the patterns are matched so that the erase gap track width is substantially the same as the servo gap track width. Such a configuration would allow the entire servo track **14** to be DC erased

[0040] **FIGS. 4-6** show each head having five patterns that may be used to perform a DC pre-erase. Such heads may

have the same number of patterns to perform a pre-erase as the number of servo channels or servo tracks **14** contained on the magnetic tape **10**.

[0041] A pre-erase process may be performed during the production of magnetic tape in order to provide a stronger signal for reading the servo pattern. **FIGS. 8A** shows magnetic tape **10** with servo track **14**, wherein the servo track **14** has been AC erased but not DC erased. As shown in **FIG. 8A**, the magnetic tape **10** has a magnetic layer **11** and a substrate **13**. The "M" stands for magnetization and shows that a portion **19** of the servo channel **14** is magnetized (e.g., by the writing of servo data). **FIG. 8B** shows the input signal **50** from a tape **10** as read by a read head of the servo pattern **14** in such a condition. The amplitude B indicates, at least in part, the strength of the signal **50**.

[0042] **FIG. 8C** shows magnetic tape **10** with servo track **14**, wherein the servo track has been DC erased in accordance with the present invention. As in **FIG. 8A**, the servo channel **14** has be magnetized by the written servo data. However, unlike **FIG. 8A**, the portion of the servo channel adjacent the servo data has been DC pre-erased. **FIG. 8D** shows the input signal **52** from the tape **10** as read by the servo read head in such a condition. The amplitude C indicates the strength of the input signal **52** from the DC pre-erased servo channel is theoretically greater than the input signal **50** from the servo channel that was not DC pre-erased. A comparison of **FIGS. 8B and 8D** shows that, in theory, the input signal **52** from a DC pre-erased servo channel is greater than the input signal **50** from a servo channel that has not been DC pre-erased. In one embodiment, a DC pre-erased channel, in theory, would provide a servo read voltage signal twice as strong as an input signal from a servo channel that has not been DC pre-erased but which had been randomly erased.

[0043] **FIGS. 9A and 9B** show a theoretical response curve **70** of the MR stripe, a theoretical input signal from a tape **71** and a theoretical output voltage **72**. The response curve **70** includes a peak **73** and a portion that approximates a linear region **74**. This response curve is sometime referred to the cosine squared response as the curve can be modeled as $\Delta R=(\delta\rho/\rho)R\cos^2\Phi$. The angel Φ being the angle between the resultant magnetization vector of the MR stripe and the applied current direction in the stripe. $(\delta\rho/\rho)$ is called the magentoresistive coefficient of the material that makes up the stripe.

[0044] This response curve in turn leads to a voltage $\Delta V=I\Delta R$, where I is the bias current of the stripe. This discussion could equally apply to giant magnetoresistive ("GMR") materials where the response is similar but modeled as a cosine curve.

[0045] In general, the output voltage should correspond to a waveform shown in **FIG. 9A** in which the input signal is within the linear region of the response curve. However, as shown in **FIG. 9B**, when the output voltage has a "rabbit ears"**75**, that the input signal extends outside the linear region and, as shown, to the negative slope of there response curve.

[0046] This condition is not desired. As such, the DC pre-erase must be such that the signal output remains within the liner region of the response curve. As such, the present invention when used appropriately allows for greater voltages of the input signal while still remaining in the linear region of the response curve.

[0047] Also, in general, the MR read sensor output voltage is a function of the thickness of the magnetic tape. To achieve higher linear recording densities the tape thickness is generally decreased to maintain magnetic bit cell stability. Hence the servo read signals may need to be increased as tape thickness decreases. As such, under proper conditions, and assuming certain system parameters of higher density recordings, performing a DC pre-erase of a servo channel enables a stronger signal to be read without going into the non-linear region of the MR read elements response curve.

[0048] In practical operation, a dual head system consisting of a servo write head and servo DC erase head would be used in making magnetic tape. The servo DC erase will erase only that part of the medium upon which will be recorded the servo format signal. For all practical purposes, the DC erase head track widths and the servo format head track widths would be the same and they would be matched up within certain engineering tolerances. That is, the magnetic tape would only be DC erased in the servo track region and not in the data track regions. This is because data zones should remain ideally AC erased so that the subsequent data written thereupon will have the highest possible signal-to-noise ration and the data will not be biased by the underlying DC erasure.

[0049] In principle one could wipe the entire tape width with a DC erase and achieve the same result on the servo track, however that may compromise the subsequently recorded data in the data track areas. Hence, while one could use a full tape width DC erase head this would not be preferred method for reasons that go beyond the scope of this document.

[0050] During manufacture, the magnetic tape would move in a transducing direction over the heads. The servo channel of the magnetic tape is first pre-erased, and then a servo pattern is written in the servo channel **14** (see **FIG. 1**). The resulting magnetic tape **10** would have a pre-aligned magnetization of the opposite polarity to that of the servo signal.

[0051] The dual module head system on one mount, the dual heads on separate individual mountsor the compound substrate head may be used to enable this concept. This concept can apply to timing based servo systems, amplitude based systems or a combination of both in some more advanced servo system. The concept will be most effective when the servo write system is uni-polar in nature and when the DC pre-erase is made using the opposite polarity.

[0052] In that the foregoing description of the present invention discloses only exemplary embodiments thereof, it is to be understood that other variations are contemplated as being within the scope of the present invention. Accordingly, the present invention is not limited in the particular embodiments which have been described in detail therein. Rather, reference should be made to the appended claims as indicative of the scope and content of the present invention.

1. Magnetic tape comprising a substrate and a magnetic layer, the magnetic tape having at least one direct current pre-erased servo track that includes servo data.

2. The magnetic tape of claim 1, wherein the servo data is time-based.

3. The magnetic tape of claim 1, wherein the servo data is amplitude based.

4. The magnetic tape of claim 1, wherein the servo data is a combination of time-based and amplitude based servo data.

5. The magnetic tape of claim 1, wherein the direct current pre-erased servo channel provides a greater input signal than one that is not direct current pre-erased.

6. A magnetic tape having at least one servo channel that is direct current pre-erased and has servo data written in the at least one servo channel, the magnetic tape made by a method comprising:

writing a servo pattern using a unipolar direct current;

prior to the act of writing a servo pattern, erasing at least one servo channel of the magnetic tape by applying a direct current of a substantially opposite polarity of the servo write current.

7. The magnetic tape of claim 6, wherein the act of writing and erasing is performed using a first head.

8. The magnetic tape of claim 7, wherein the act of writing and erasing is performed using a first head further comprising providing a head with a time-based servo pattern.

9. The magnetic tape of claim 7, wherein the act of writing and erasing is performed using a first head further comprising providing a head with an amplitude-based servo pattern.

10. The magnetic tape of claim 7, wherein the act of erasing at least one servo channel of the magnetic tape is performed by first passing a portion of the magnetic tape that includes the at least one servo channel to be erased over the first head.

11. The magnetic tape of claim 10, wherein the act of writing a servo pattern in the at least one servo channel of the magnetic tape is performed by then passing a portion of the magnetic tape that includes the at least one servo channel to be written over the first head.

12. The magnetic tape of claim 6, wherein the act of erasing and writing are performed using two heads.

13. The magnetic tape of claim 12, wherein the act of erasing is performed by a first head and the act of writing a servo pattern is performed by a second head.

14. The magnetic tape of claim 13, wherein the act of erasing by use of a first head, further comprises using a first head that includes a time based servo pattern.

15. The magnetic tape of claim 13, wherein the act of erasing by use of a first head, further comprises using a first head that includes an amplitude-based servo pattern.

16. The magnetic tape of claim 13, wherein the act of erasing by use of a first head, further comprises using a first head that includes an erase pattern having a erase gap track width that is substantially the same as the servo gap track width.

17. The magnetic tape of claim 13, wherein the act of erasing by use of a first head, further comprises providing a first head that is one of a thin film head, ferrite based head, and surface thin film head.

18. The magnetic tape of claim 13, wherein the act of erasing by use of a first head, further comprises providing a first head that is a ferrite MIG type head.

19. The magnetic tape of claim 13, wherein the act of writing by use of a second head, further comprises providing a second head that is one of a thin film head, ferrite based head, and surface thin film head.

20. The magnetic tape of claim 19, wherein the act of writing further comprises writing at least one of an amplitude-based and timing-based servo pattern.

21. The magnetic tape of claim 12, wherein the two heads are located on a single mount.

22. The magnetic tape of claim 12, wherein the heads are located on separate mounts.

23. The magnetic tape of claim 12, wherein the head used to erase is located on a separate tape deck from the head used to write a servo pattern.

24. An apparatus for use in pre-erasing magnetic tape, comprising:

a housing supporting at least one head, wherein at least one head includes a pattern to direct current pre-erase at least one servo channel on the magnetic tape.

25. The apparatus of claim 24, wherein the heads are thin film heads.

26. The apparatus of claim 24, wherein one head is a surface thin film head and the other is a low inductance surface thin film head.

27. The apparatus of claim 24, wherein at least one of the two heads is ferrite MIG head.

28. The apparatus of claims 25, 26, or 27, wherein at least one head includes a pattern used to erase pattern each servo channel of the magnetic tape.

29. The apparatus of claim 24, wherein the housing supports at least two heads, wherein at least one of the heads is used to direct current, pre-erase at least one servo channel of the magnetic tape.

30. The apparatus of claim 29, wherein the pre-erase head is a ferrite based head.

31. The apparatus of claim 29, wherein the head from writing a servo pattern is selected from one of a thin film head, ferrite based head, and surface thin film head.

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